TEACHER'S MANUAL

FOR

PHYSICS

Middle School Stage

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FOREWORD

THE NCERT has been preparing textbooks in different science subjects for the middle school stage. Initially the textbooks were prepared on an experimental basis and tried out in selected Delhi schools. The teachers of these schools were oriented to the contents and methodology, and cyclostyled guidance materials were supplied.

From the experience obtained from visits to schools and the reactions of teachers, it was felt that a detailed guidebook for teaching physics was necessary so that the teachers could do full justice to the new curricular materials

The present title is a companion volume of the textbook on Physics Part II for the middle school stage, which covers the areas on 'Forces', 'Work', 'Machines', 'Thermal Phenomenon', 'Heat and Work' and 'Transition of Substances from One Aggregate State into Another'.

A general discussion of organising the content, teaching procedures and evaluation of pupil knowledge is followed with a detailed methodological analysis of the content covered in the textbook to make the teacher aware of the fundamental concepts involved and the difficulties that he may find in elucidating difficult concepts. A brief outline of the lessons are then given to help the teacher make his lesson plan.

Though the original textbook has undergone a revision, the essential concepts of physics remain the same and consequently the content and methodological analysis would continue to be useful to the practising teacher.

The main credit for preparing this book goes to Dr. A. A. Margolis, our UNESCO Expert in the Department of Science Education, and Mrs. N. Mitra, Shri Chhotan Singh and Shri H. L. Sharma have developed the different chapters of the manuscript and Dr. R. N. Rai has helped in editing.

It is hoped that the book will prove useful to the teachers. All comments and criticisms would be welcome.

S. V. C. AIYA
Director
NCERT

April 1971
New Delhi

CONTENTS

CHAPTER 1

Planning the Progress of Teaching

BEFORE A TEACHER begins work he should make a plan of work. The following three plans are suggested.

1. The general annual plan.
2. The topical plan.
3. The lesson plan.

1. The annual plan contains the distribution of periods according to the curriculum of the school and the syllabus in physics on individual topics. This plan should indicate the number of hours on discussions, on written tests, on laboratory work and on revision. The distribution of periods between individual topics should be done taking into account the amount of the teaching-learning material on each topic and the importance of the individual topics.

2. The topical plan may comprise of a topic or a section of the syllabus and should contain:

(i) The calendar dates of the lesson.
(ii) The topics of individual lessons.
(iii) The assignments for review.
(iv) An indication of the method of conducting the work—the teachers' talk with demonstration, laboratory work, excursion, solving problems and written test work.
(v) The list of all demonstrations on the topic. (It is convenient to have the list of all the demonstrations on the topic in separate cards.) In this case the topical plan should contain only the number of the card which simplifies the business. On the reverse side of the card the teacher may enter his notes concerning the most favourable conditions for the demonstration.
(vi) The set of problems on this topic to be solved at home and additional problems for the gifted pupils.
(vii) The teacher should take note of what knowledge and skills on this topic are to be learnt by pupils. Thus on the first topic on the course of physics for Class VII, the teacher should write down :

Knowledge · The concepts of mechanical motion. The concept of relative motion and rest Classification of mechanical motions : (1) by their trajectories . rectilinear and curvilinear motion, (2) by the type of the motion . translatory rotatory and oscillatory motions and (3) by the speed of the motion · uniform and non-uniform motions. The peculiar features of each type of motion Methods of measuring time. Uniform and rectilinear motion The speed of uniform motion. Non-uniform motion. The average speed of non-uniform motion. Newton's first law Inertia of bodies. The mass as the measure of the inertness of the body. The concept of balancing forces. Uniform motion under the action of balancing forces.

Different types of friction · The methods of measuring the force of sliding friction Independence of the force of friction of the surface area of the body. Dependence of the force of friction on the weight of the body (for a horizontal section of the path) and on the nature of contacting surfaces Methods of reducing harmful friction in technology and increasing useful friction. Action and reaction.

Skills To measure · a weight (with a dynamometer) the force of sliding friction in uniform motion, the force of rolling friction, the force of friction at rest To solve problems on uniform motion, to calculate the average speed of non-uniform motion, to be able to use in practice the phenomenon of inertia

3. The teacher should have a detailed plan of each lesson The fresh teacher just beginning his school teaching career should have an even more detailed plan containing his notes on the lesson when any new material is to be introduced.

The detailed plan of the lesson should contain :

1. The topic of the lesson.
2. The aim of the lesson.
3. Questions and problems for revision, (question or problems on the material studied earlier.)
4. A brief introduction to the new topic
5. Writing the topic on the classboard and dividing it into sub-topics
6. Demonstration and audio-visual aids to be used at the lesson.
7. The main points in the new material.
8. Recapitulation.
9. Home task.

The annual plan for the course of Physics Part II

The total number of periods in a school year is 105. In view of the size and scope of the instruction material as well as the difficulty in understanding, it

is advisable to distribute this number of periods among different individual topics as follows.

I. Mechanical Motion	— 17 periods
Out of this for the Study of the topic itself	— 14 periods
for laboratory work No 1 —Measuring force of friction	— 1 period
for revision	— 1 period
for written tests	— 1 period
II. Composition of Forces—Equilibrium of bodies	— 8 periods
Out of this for the study of the topic itself	— 7 periods
for laboratory work No 2—Determining the centre of gravity of flat bodies	— 1 period

Note : *Revision may be done at each lesson.*

III. Work and Energy	—20 periods
Out of this for the study of the topic itself	—17 periods
for laboratory work No. 3—Conditions of equilibrium for the lever and the pulley	— 1 period
for revision	— 1 period
IV. Thermal Phenomen	—15 periods
for the study of the topic itself	—14 periods
	— 1 period

Note : *No special time to be allocated on revision.*

V. Heat and Work	—21 periods
for the study of the topic itself	—17 periods
for laboratory work No. 5 comparing the quantity of heat by mixing cold and hot water	— 1 period
for laboratory work No 6 determining the efficiency of a heater	— 1 period
for revision	— 1 period
for written test	— 1 period
VI. Change in the state of substances	—18 periods
for the study of the topic itself	—14 periods
for laboratory work No 8—Observation of heating and melting of naphthalene for laboratory work No 9—Observation on heating and boiler water	— 2 periods
for revision	— 1 period
for written test	— 1 period
VII. Revision of the course and preparation for examination	— 3 periods before winter examinations and 3 periods before summer examinations.

The meaning of and the plans for the demonstration and laboratory experiment

The peculiarities of physics instruction in Class VII have already been mentioned earlier. The abstract thinking having not yet fully developed, pupils cannot assimilate well enough the portions dealing with mechanics, which is one of the most complex and abstract sections of this course of physics But this is true only if the discussion of theoretical problems is not supported by appropriate experiments clarifying all the related concepts. Unless the demonstration-experiments are not interesting it fails to impress pupils emotionally The technique of performing experiments in mechanics is very simple and the apparatus involved are very unsophisticated. Hence it is the skill of the teacher on which the effect of these simple demonstration depends. It is the teacher who is responsible for impressing the pupils emotionally and consequently for keeping these experiments in their memory for a considerable period of time. Psychological research on man's memory shows that anything which is beautiful and emotionally appealing creates a more stable impression for a longer period. Consequently preparing for the demonstration to be performed for the lesson of mechanics, the teacher must be capable of not only making the experiment clearly visible, but also simple and aesthetically appealing. If the teacher has carefully planned the demonstrations on a topic, he will always be able to prepare, with his pupils' assistance, these very simple devices and materials.

The list of minimum obligatory demonstrations on this topic are given later.

The role and place of problems in the course of physics

Solving problems by pupils plays a great part in learning physics lessons. Solving problems is one of the effective measures to counteract the pupils' formal approach to physics classes. The teacher of physics should make his pupils realize that pupils' knowledge of physics cannot be rated high if they fail to solve problems. If the pupils have been taught only some concepts, phenomena and regularities in nature, their knowledge of physics remains only formal. On the contrary pupils' ability to solve physical problems show that they can make use of their theoretical knowledge and understand what the concepts, phenomena and regularities actually mean In order to make problem-solving an integral part of any lesson in physics, the teacher should have a special book of problems. From the number of problems in the form of exercises in the textbook, some minimum must be selected by the teacher as home assignments for pupils. Most of the problems in this physics course are only qualitative, because the pupils' insufficient knowledge of mathematics does not allow the use of the analytical method in introducing individual problems. When the teacher discusses the topic motion, he only gives the formula for uniform and non-uniform motion, the rest of the problems being dealt with without the use of mathematical formula.

Normally the teacher uses physical problems of following types :

1. Problems on calculation.
2. Qualitative problems
3. Experimental problems.

Problems on calculation can be solved if pupils are aware of physical laws and can use mathematical methods.

The advantage in problems of this type is that they help to establish inter-relations between the teaching of physics and the teaching of mathematics Such problems are widely used for the pupils at the higher stage At this stage, the problems of this type may be only limited to the laws of motion. The disadvantage of the problems of this type is the considerable amount of time required for their solution and the fact that the mathematical aspect has to be given more attention than the physical aspect.

Qualitative problems are widely used in teaching physics at this stage. Here the pupils are involved in some problems associated with the qualitative aspect of a physical phenomenon. These problems are solved by a logical reasoning based on the laws of physics No mathematical operations are involved in solving these problems The advantages of types of these problems are the following.

(i) Qualitative problems contribute to ensuring pupils' better knowledge of theory and ensure a better retention of the material.
(ii) They serve as an effective means of evaluating pupils' knowledge.
(iii) They increase pupils' interest in physics and ensure a better assimilation of the material.
(iv) They develop pupils' logical thinking.
(v) They require less time than problems on calculation.

Consequently this type of physical problems should be used most widely by the teacher in his work.

The third type of physical problems also plays a great part in physics teaching The experimental problem is a specific kind of the qualitative problem.

A problem of this type is given to the pupil as an experimental assignment. Pupils are offered a simple experiment which they should explain afterwards. Evidently the teacher has to undertake some additional work to prepare an experiment involving such problems but it deserves effort because pupils' interest in physics increases considerably These problems stimulate pupils' creative approach to learning They make pupils take to such experiments which in turn increase pupil's ability to observe things minutely.

Evaluation of pupils' skill and knowledge

Evaluating pupils' knowledge and skill plays an important part in the process of teaching. One of the most important forms of evaluation is the revision of the material of the previous lesson by giving questions to students and making them

answer these questions. With very few exceptions every lesson should include this form of evaluation. The aims to be achieved by this form of revising the material are :

(i) Ascertaining that the pupils have assimilated the material of the previous lesson.
(ii) Elaboration of the concepts and regularities previously introduced by putting questions to pupils provided such questions can be answered by giving various examples and by solving problems.
(iii) Developing pupil's skills in experimentation provided that a pupil's answer is accompanied by his demonstration and the same experiments which were shown by the teacher at the previous lesson.
(iv) Ensuring a better revision of the study material by pupils.
(v) Teaching students to work independently and to be prepared to answer at every lesson
(vi) Ensuring a better evaluation of pupils' skills and knowledge. The teacher can follow the day-to-day progress of the pupils on the basis of the marks which he gives to the students. Thus the teacher can secure a better assessment of his pupils' knowledge and skill than it is possible by the system of the examinations taking place twice a year.
(vii) Finally, this form of revision enables the teacher to be always aware of the speed at which the new material is introduced.

In view of this the problems involved in revising the study material should be given the teacher's consideration when he prepares for each lesson in physics. This system of revision can be further divided into following three forms which are used by physics teachers.

(i) Revision of the material by students on the blackboard.
(ii) "Condensed" individual questioning of pupils at the blackboard.
(iii) Question to the entire class (without calling students to the class board).

One common feature of all the three forms is the equal amount of time allocated for this form of work. If the duration of one period is 35 minutes unless the lesson is not a special evaluation lesson, the teacher should allocate 8-10 minutes on revision. Consequently to use this short period of time most effectively, the revision part of the lesson should be very well planned

Another feature of revision, irrespective of the form of revision, is that during the same time the teacher should check up how the pupils assimilate the current material along with the retention of the material previously studied.

Finally in revision, all the material should include solving of physical problems. Additional work should not be given to the student unless he solves a problem. In classes 6-8 it is sufficient to give pupils one theoretical question and one

problem. If the question is on the current topic the problem should be on the material previously studied or *vice-versa.*

Let us now consider the peculiarities of the above mentioned forms of revision.

1. *Questions to individual students*

The teacher puts a question to the whole class and having thus drawn pupils' attention to this question, he calls one of the pupils to the blackboard and asks him to give his answer or to solve the problem The pupil should illustrate his answer by a sketch, a table, a chart or some simple experiments. While he is solving the problem at the classboard, the teacher keeps the whole class in his view and asks the rest of the pupils to be ready to take part in the discussion. He should not interfere with the pupil's answer and after the pupil has finished his answer, the teacher asks several pupils to speak up on the errors or distortions and to correct them, and thus a further analysis of some parts of answer which is being discussed, is done.

In using this form of revision, it is especially important to check up and remove all the misunderstandings and deviations from the correct understanding of the problem which arise in the class. After the pupil has completed his answer, the teacher should tell him the marks secured by him on the merit of his answer explaining why it is the appropriate marks. This is important because the teacher should get the pupils used to the objective requirements for evaluating a good answer which should be uniform in respect to all pupils without any exception.

2. *The "condensed" individual questioning of students on the classboard.*

When the teacher uses this form of revision he puts two or three questions to the class (or three problems) and calls to the blackboard two or three pupils at a time. In this case one of the pupils solves problems on the classboard, the second prepares an experiment and the third answers a question which does not require any special preparation When this form is used, it is important to give some assignment to the rest of the class (either to solve a problem or to listen to the pupils' answers). When the teacher uses this form of revision, he should make all the class participate in the analysis of the pupils' answers.

This form of revision should be given more prominence in the work with senior pupils whose attention is more concentrated than the attention of the pupils of classes VI-VIII. However, this form of revision may be used successfully in classes VII-VIII provided the teachers organise this work properly.

3. *Group questioning.*

In this form of revision the teacher does not call pupils to the classboard but puts questions to the whole class. The students prepare their answers and raise

their hands. The teacher asks individual students. This form of revision is especially advisable when it is necessary to review quickly some material which is needed for the introduction of a fresh material, or revision of a topic or sub-topic. If in the course of such work some students give two correct answers, the teacher may give them, the highest marks for encouraging them.

In addition to the forms of evaluation mentioned above, some other forms of evaluation should also be used.

(i) Checking the students written homework

At the beginning of the lesson the teacher should ask the pupils to take out their notebooks and open the pages with the hometask Then the teacher asks the individual difficulties experienced by the pupils in course of doing their home work. Walking between the rows, the teacher inspects the pupils' notebooks paying attention only to whether the work was done at all, whether it was done neatly and correcting such mistakes which are evident. Another method is to check only some of the notebooks, for example, the notebooks of those pupils who were called to the blackboard. In addition, the teacher should from time to time (for instance once in a fortnight), take his students' notebooks for checking them at home. The pupils should be aware that their home work is checked up systematically.

(ii) Written tests

After studying one topic or a number of related sub-topics, the class should be given one common written test. All such tests should contain only physical problems without any theoretical question. To secure the objectivity of evaluation, each written test should contain 4-6 variants of the same difficulty so that copying should be impossible. On checking the tests and evaluating them the teacher should analyse the typical mistakes made by the pupils at the lesson. The final marks which are given to the pupil at the end of the school year, should be based on the average marks given to the pupil during routine questioning, i.e., the marks for his written tests and the marks received by the pupil at the examination.

Pupils of this age group (classes VI-VIII), who are very emotional and heterogeneous from the point of the level of the knowledge and the speed of perception, benefit more if a sort of combination of group method and the individual method of revision are used by the teacher. The limited amount of time necessitates a most accurate formulation of questions and problems. These must be very simple in style and understood by pupils quite clearly Many young teachers cannot make their questions concise and accurate. This causes difficulties for many pupils. A simple recommendation may be given. Intended question should not be set up on the spot but well thought out and recorded in the lesson plan. To maintain the activity of the pupils during revision, the teacher should not correct pupils mistakes himself but invite other pupils to do it. Only if the entire class fails to correct

the mistake, the teacher should help pupils One typical feature of the process of revision in classes VI-VIII is the necessity of putting questions and giving problems which involve the understanding of phenomenon or a regularity in some processes associated with the application of these laws and regularities. The teacher should not be very particular about an accurate working of a concept or basic physical quantities, because most concepts and regularities are not given to pupils in the most accurate scientific formulation but only in approximately correct terms. The most important condition is that the pupils should not learn by heart the various definitions and concepts, but understand them clearly and be able to implement them in solving various problems Consequently, little can be achieved pedagogically by putting questions requiring only some formal answers concerning definitions. Another feature of revision in these classes is, whether the teacher can establish contact between the student answering at the classboard and the rest of the students If the teacher fails to achieve this, the attention of the pupils is switched over to items which have no relation to the studies.

Mechanical Motion

Topic no. 1.

Fundamentals of Mechanics

I. The significance of the topic

Mechanics is one of the most complex sections in the course of physics, not only at the initial stage of instruction but also for senior students at the second stage of instruction One of the main difficulties lies in the fact that this section deals with abstract material, the assimilation of which requires the intelligence of a mature mind. It is well known that abstract notions are difficult to understand, specially when we deal with young pupils of Class VII This does not mean, however, that pupils cannot assimilate this material at all. In order to achieve this, it is important for the teacher to select the best methods of introducing the topic and to find the best ways to facilitate the retention of this material by the pupils One of the most common errors on the part of a young teacher is that proceeding from his own knowledge, he considers the initial concepts of kinematics very simple and explains these to his pupils at the lessons too quickly. This leads only to a more or less formal covering of the material, without developing any meaningful understanding. To avoid this mistake, careful consideration should be given to the methods of formation of each concept of kinematics. This can be achieved through a logical system which is based on the life experience of the pupils themselves, demonstration experiments and solving various types of problems.

Another very important factor is to make these lessons interesting to the pupils Without this, lessons in mechanics will seem dull and uninteresting to the pupils, which will largely determine their attitude to this subject This difficulty may be overcome if the lesson is conducted using appropriate method, *i e*, when the teacher talks with the students, the talk is accompanied by interesting experiments and solution of various interesting physical problems Since one of the principal methods, which the physics teacher uses at the first lesson, is the laboratory experiment method, the teacher faces important problems It is important that the students should develop the skills of observation, comparison and drawing conclusions, and they should learn how to observe the action of physical laws in the phenomena taking place in their life. The concepts of mechanics should be based on concrete physical idea. During the lessons the students should be given a chance of active observation of the motion of the body during the demonstration experiment. They should be given tasks involving observations of various phenomena out-of-the-class surroundings, and they should be taught how to estimate the characteristics of motion. To make the students more active at the lesson by observation, it is desirable to make them answer questions on the blackboard and to support their oral answer with simple experiments in mechanics which were shown by the teacher at the previous lesson. Finally, the topic "Elements of Mechanics", plays a great part in the course of physics as a basis for all the subsequent sections of such a course Experience shows that if students have good knowledge in mechanics, they easily assimilate the other concepts of the physics course too.

While introducing this topic, the teacher should remember the important condition, *viz*, it is much easier to train than to undo the previous wrong training and train them again, since in the syllabus, mechanics is studied twice in the first and the second stages of the course. It is important, therefore, to give the correct concept of physics to avoid repetition of the same at the second stage Consequently, this should be done in such a way that at the second stage these concepts could be expanded and elaborated. For example, uniform translatory motion is studied only at the first stage and so it is necessary to give and explain scientifically the definition of uniform translatory motion as well as the notion of the velocity of uniform motion. Non-uniform motion is studied both in class VII and at the second stage Therefore, in class VII, the teacher gives only the definition of the average speed of non-uniform motion and then this concept is elaborated at the second stage Instantaneous speed of non-uniform motion is discussed. It is important to know which concepts in this topic are to be given only once and are not to be discussed at length again at a later stage. Therefore, these concepts should be explained correctly, and those concepts which will be dealt with also at the second stage, should be explained in such a way that these concepts could then be elaborated without repeating them. This topic is important not only from the point of view of amount of knowledge it gives to pupils, but also because it has a

polytechnical significance. Acquainting the students with the concepts of friction enables them to understand the principles on which the motion of the various kinds of transport, are based and to understand the principle of the transfer of motion from the engine to various parts of the machine. While learning the phenomenon of inertia and its measurement, pupils can understand why the base plates of various machines are made heavy, and how inertia of motion is used in transport vehicles. For instance, they will understand why, when approaching traffic light, motor car drivers switch off the engines but the vehicles move on. The study of simple machines enables one to understand the principle of working of the water lifting machines fitted in wells, windlass, lifts, cranes and many other machines, since the most modern complex machines are only combinations of various simple machines.

II. Content of the topic

The first topic "Elements of Mechanics" consists of three sections .

1. Fundamentals of kinematics
2 Newton's first law
3. Friction.

1. Fundamentals of kinematics.

This section comprises of the following ·

(i) The concept of mechanical motion of bodies.
(ii) The concept of relativity of rest and motion.
(iii) Classification of motion by the trajectory of motion : rectilinear and curvilinear, by the form of motion: translatory, rotatory and oscillatory motion, by the speed of motion uniform and non-uniform motion.
(iv) Measuring time
(v) Study of uniform rectilinear motion
(vi) The speed of uniform motion.
(vii) The formula of the distance covered by bodies in uniform motion.
(viii) The average speed of non-uniform motion.
(ix) The distance covered by bodies in non-uniform motion.

2. Newton's first law

The topic "Newton's first law" comprises of the following sections·

(i) The definition of Newton's first law.
(ii) The concept of inertia of bodies.
(iii) The possibility of the existence of uniform motion of bodies under the action of mutual balancing forces
(iv) Elaboration of the definition of Newton's first law.

3. Friction.

The topic includes the following sections :

(i) The substantiation of the existence of friction.
(ii) The nature of friction
(iii) Three types of friction.
(a) Sliding friction.
(b) Rolling friction
(c) Static friction
(iv) Methods of measuring forces of friction and coefficient of friction.
(v) Means to decrease harmful friction in technology.
(vi) Means to increase useful friction in technology
(vii) Elementary concept of Newton's third law.

This is the scope of the theoretical material stipulated in the syllabus for class VII and consequently this material is compulsory for all experimental school pupils. The study of the fundamentals of such a science as physics, which is basically experimental, is not even thinkable without some amount of experimental skills and knowledge being displayed by the pupils. The syllabus, therefore, envisages a number of laboratory experiments to be performed by pupils under the teacher's supervision. The syllabus envisages assignment in laboratory works on the measurement of the coefficient of friction between wood and wood.

III. The key questions of the topic.

The study of the fundamentals of mechanics being with the study of kinematics, *i.e.*, the section of mechanics which deals with the laws of mechanical motion without going into what causes this motion. Hence, mechanical motion is the first concept of physics which should be explained to pupils Everyday we observe a great number of various types of mechanical motion. Motor cars, trains, vessels, clouds, water in rivers, the moon, the artificial satellites of the earth, the earth itself and the sun are all in mechanical motion. Hence any displacement of bodies and change of their positions in space, is called mechanical motion. Following the teacher's explanation of mechanical motion, pupils themselves can give many examples of mechanical motion on the basis of their observations. After this the teacher should show some demonstrations which illustrate the mechanical motion on the basis of their observations. After this the teacher should show some demonstrations which illustrate the mechanical motion of different bodies. The teacher, however, should bear it in mind that the given definition is not strictly precise. This definition is to be elaborated at further stages. The teacher will have a possibility to do it when discussing relativity of any mechanical motion as well as of rest which is a particular case of motion The idea of the relativity of motion is an important factor in the formation of pupils' abstract thinking.

The idea of relativity of motion begins to form in the course of physics for class VII and during all the following years of instruction, the teacher should always be cautious about it in all the other sections of physics. Dealing with the topic "Fundamentals of kinematics" the teacher gets an opportunity to introduce the idea of relativity with the example of mechanical motion and rest and with the example of the speed of motion of bodies.

The idea of relative motion of bodies is best explained if the teacher begins with an analysis of a few examples. Thus, if we travel by steamer along a quiet river and do not hear the sounds of the working engine and we do not see the outside objects, we shall form an impression that we and the bodies on the table, the lamps, etc. are in the stage of rest provided we are sitting in a cabin. But if you look at a building or trees on the shore we shall see at onee that we and the steamer too, are in motion. The same impression we form if we find ourselves in an aeroplane If the plane is flying smoothly and there are no air-pockets we shall think that we and the bodies around us as well as the plane itself are not moving These and similar examples show that to determine the state of motion or the state of rest one must have some other objects besides those which are under consideration. From this it follows that the steamer is in motion against the shore, the train against the railway track, the motor car against the trees along the highway etc Consequently, to determine the state of rest or the state of motion of a body, it must be compared with an other fixed body. If we study the state of a body and have chosen another body against which we want to determine the state of the first body (frame of reference) then it is rather simple to determine the relative state of body If in the course of time, the distance, which separates the first body from the second, does not change, it means that the given body is at relative rest If this distance changes, the given body is in the state of mechanical motion against the body taken as the reference. But the examples, of the body taken as reference cited above as railway track, the trees along the highway and the other objects are themselves in motion together with the earth.

They are taken for stationary objects only with some reservations. To make the concept of relative motion and relative rest more concrete, pupils should be shown some simple but very important demonstrations to secure a good retention of the idea of relativity. A few of such demonstrations will be given later in the complete list of all the demonstrations on this topic. Here we shall touch upon only one simple demonstration

Let us place a small carriage on the demonstration table On this carriage we place a block. On the same demonstration table, we place another block beside the carriage with the block on it. The second block should be provided with a small flag. Our first question will be the following :

In what state is the carriage and the block on it against the other block ? As the distance between the carriage with a block on it and the block which is

on the table beside it, does not change with time, we can draw the conclusion that the carriage is in the state of rest against the body of reference If the carriage with the block on it is pushed a little, the distance between the carriage, with the block on it and the other block beside it, will change and so the former will be in motion against the latter taken as the reference At the same time the block on the carriage will be in state of relative rest with respect to the carriage. If instead of the carriage and the block on it you put on the demonstration table two similar winding models of motor-cars and release them, then both the models will be in state of motion against the body taken as the reference that is, the other block and at the same time either model will be at rest against the other which is moving at the same speed After this demonstration the pupils should themselves give examples of the relative motion and relative rest of some bodies. The teacher now can give a more accurate definition of mechanical motion which could be written down by the pupils in their notebooks *Mechanical motion is any change in position of a body against other bodies which are assumed not to be in motion.*

The next point is how to classify the various types of mechanical motion. First of all, we shall divide all the types of mechanical motion into rectilinear and curvilinear types according to the trajectory of motion The classification is accompanied by simple and clear demonstrations and does not cause any difficulty in understanding. More difficult is the classification of motion according to its type. First we shall consider translatory motion. The teacher should begin with the demonstration of the different types of simple translatory motion.

For example, the teacher may demonstrate the rectilinear translatory motion of a model motor car, motion of a table drawer, upward motion of a load using a fixed pulley and then show the motion of a model motor car on a curvilinear track. The teacher should draw pupils' attention to the fact that translatory motion can be both rectilinear and curvilinear. The teacher should also draw pupils attention to the fact that in all the examples cited above there is one common feature, *i.e.*, all the points of the bodies move along similar trajectories and cover similar distances during the same time. A special device can be used for a better understanding of the specific features of translatory motion. This is a piece of plywood which represents the absolute solid body in which there are some holes with coloured pieces of chalk inserted into these holes. These coloured pieces of chalk represent the individual material points of the body If we put this device on the classboard and move it along its surface, we shall get similar rectilinear and curvilinear trajectories of individual points of the body which is in translatory motion. The main characteristics of translatory motion is :

If a straight line connects any two points of body and remains parallel to itself when the body moves then the motion of the body is translatory. Thus, translatory motion is the simplest form of mechanical motion; because all

points of the body in translatory motion describe similar trajectories Hence, it is sufficient to analyse the motion of only one material point of this body.

Rotatory and oscillatory motion should be analysed in the same sequence, *i e*, (i) examples of rotatory motion in practice (ii) demonstration of rotatory motion (iii) specific features of rotatory motion (iv) application of rotatory motion in technology

The analysis of the topic "uniform motion" normally is not difficult and pupils easily understand it. However, the concept of speed as a distance covered in unit time should be formulated very clearly and its introduction should be followed by solving problems on the calculation of speed in different units. Pupils should know that to compare two speeds, these speeds should be expressed in similar units. Pupils should be given quite a number of problems on the laws of uniform motion

$$(S=vt;\ t=\frac{S}{v},\ v=\frac{S}{t}).$$

At the first lesson, the teacher can give the formulas of uniform motion in words and then use the related symbols which are required in solving problems Special attention should be given to the comparison of the speed of uniform motion and the average speed of non-uniform motion. It follows from the formulas $V=\frac{S}{t}$ and $V_{av}=\frac{S}{t}$ that the method of calculating these two speeds is the same. However, the physical meanings of these quantities are different.

If we know that a body is moving uniformly at a speed of 60 kilometres per hour it means that in any equal intervals of time this body covers equal distance. Thus, in this example the body covers 60 kilometres in each hour, each minute the body covers 1 kilometre and each second the body covers 1/60 kilometre. Consequently, we can say that the speed of uniform motion characterises the speed of the motion of this body during any interval of time or for any part of the distance. The average speed of non-uniform motion, which is equal to 60 kilometres an hour, has quite different meaning. If it is known that a train moved at an average speed of 60 kilometres per hour this means that for one hour it was moving at a speed of 60 kilometres per hour. During another period the speed might have been 70 kilometres per hour and at the stops the speed of the train was zero The average speed of non-uniform motion characterises the speed of motion during the total period of its motion or for the entire distance. Hence, there is a clear difference between the speed of uniform motion and the average speed of non-uniform motion. The average speed of non-uniform motion is numerically equal to the speed of such uniform motion, where distance and time are similar to those of non-uniform motion.

One of the most difficult problems of this topic is the introduction of Newton's first law. This is important because Newton's first law enables the teacher to bring the students to the understanding of the force as a dynamic factor causing the change in the body's speed. On the other hand this law enables one to analyse inertia as a feature, characteristic of all the bodies in nature Finally, Newton's first law provides a method of measuring the force of friction which is very important in modern technology While explaining Newton's first law the discussion should begin with a simple demonstration. This experiment consists of the study of the motion of a ball along the horizontal planes made of different materials The surfaces may be of sand, plywood, glass, etc Each time the distance covered by the ball should be marked. Though the pupils have not yet begun studying friction, when the teacher asks why the ball stops, most of the pupils are able to give the correct answer that it is the friction which stops the ball's motion. Then the teacher draws pupils' attention to the fact that when friction decreases, the distance covered by the ball increases Now the question arises what would happen if the friction were zero. It is evident that the motion in this case would continue indefinitely at constant speed and along the same straight line This conclusion was first drawn by the great Physicist Galileo. How can we verify this conclusion ? Evidently, this cannot be verified by direct experiment because it is not possible particularly on our planet, to create such conditions, under which no force would be acting upon a moving body. However, one can verify this indirectly in the following way In any case when a body changes its speed either in magnitude or in direction, it is possible to find a cause, *viz.*, the force which compells this change. A body gains in speed when falling towards the earth. The cause is the terrestrial force of gravitation. Also when we switch off the engine of a moving motor car, the motor car slows down because of the friction with the earth and the resistance of the air.

Newton's first law may be formulated in the following way. Every body continues in its state of rest or in the state of uniform rectilinear motion in absence of any external force acting upon the body. This definition is rather similar to that which was given by Newton himself. It is difficult or even impossible to carry out on our planet direct experiments proving the validity of Newton's first law.

A teacher of physics should also bear in mind that Newton's first law reflects, in essence, the idea of conservation of motion,

With Newton's first law is associated the concepts of an inertial system and that of inertia

'The inertial system is a system which is connected to a body at rest or to a body in uniform rectilinear motion with respect to the first body. All physical laws remain unchanged in inertial systems Hence, an inertial system of reference is a system which complies with Newton's first law.

Newton's first law is often called the law of inertia. Inertia is a basic property of matter to preserve the relative state of rest or the state of uniform rectilinear

motion unless an outside force is acting on it. This property is characteristic of all bodies. However, quantitatively, this property is manifested differently in different bodies. To show this, the teacher may carry out an experiment similar to rolling the ball along the inclined plane. This is done in the following way.

On the horizontal portion of the table, we put a piece of woollen cloth to achieve the constant force of friction. We tell the pupils to observe the rolling of *different* balls from the same height. The experiment shows that with the increase in the mass of the ball the distance covered by it, increases. Consequently, it is the mass of the body on which the inertia of that body depends. The bigger the mass is the greater is the inertia of the body, *i.e.*, the body with a bigger mass keeps to a greater extent its state of relative rest or the state of uniform rectilinear motion. Everybody knows from experience that if there are two railway wagons on a horizontal portion of a railway and one of the wagons is loaded and the other is empty, then the empty wagon can be displaced with less force than the loaded one. Similarly, if we have two railway wagons moving along the horizontal portion of a railway track it is easier to stop the empty wagon.

It is said, therefore, that the mass of the body is the measure of the inertness of the body. Class VII pupils know from the course of physics for class VI what the weight of a body is. It is necessary, therefore, to draw their attention to the fact that the mass of a body as one of the most important properties of matter is proportional to the weight of the same body, *i.e.*, if we express the mass of a body by M and its weight by P, then, M=kp. of two bodies by their weights. The greater is weight of a body the greater is its mass. At the second stage of instruction pupils studying Newton's laws get more elaborate data on the mass of body. The concept of the mass is considered to be very difficult particularly for class VII pupils. Therefore, the more precise definition of this concept has been included in the syllabus only at the second stage. Class VII pupils will deal with this concept in the course of physics only, when they take up calorimetric calculations. But in such calculations the mass of a body does not serve as a measure of its inertness but a quantity of the substance. Inertia of bodies may be shown by various demonstrations. The list of all the demonstrations on this topic are given at the end.

It is important to analyse each experiment and to explain it to the pupils. Thus, explaining the experiment of fixing the hammer to a handle, the pupils should be told that when the hammer head and the handle move downwards, both the head and the handle possess inertia of motion. When you strike the handle (its end) on the table, the motion of handle stops because a force is applied, whereas, the hammer head continues moving because of inertia and consequently the handle fits into the hammer head. After this the motion of the hammer head stops because of the force of friction. After the introduction of the law of inertia, the related experiments explaining qualitative and especially experimental aspects the following questions may be put to the pupils.

In accordance with the Newton's first law a body may move uniformly if no force is acting upon that body At the same time we know very well that on levelled road the uniform and rectilinear motion of a motor car or some other vehicle under the influence of some force can be observed. This fact apparently contradicts.

The teacher may easily show that there is no contradiction. Actually bodies may be in the state of relative rest or uniform rectilinear motion in the following cases : (1) if no force is acting upon body or (2) if some balancing force is acting upon a body Two forces are called balancing forces if they are of equal magnitude and act on the same body along the same straight line but in opposite directions, the resulting force being equal to zero. That is why a motor car can move uniformly on the track In this case the attractive force is acting upon the car in one direction and the total force of resistance equal in magnitude is acting along the same straight line but in the opposite direction.

F traction= —F total resistance.

To prove that the teacher may perform two demonstrations, to show that the state of relative rest or the state of rectilinear motion does not change if two balancing forces are applied to a body. In this experiment a wooden block with two books at the ends is placed on the demonstration table. The block is in equilibrium in this state.

If two dynamometers are fastened to the hooks and two equal forces are applied to the dynamometer, it will be seen that the state of rest will not change. The teacher may also show another experiment with the help of inclined glass tube containing some viscous liquid that a metal ball falling in the tube, moves uniformly. Here, two forces of equal magnitude are acting on the fall in opposite direction.

The pulling force and the force of resistance are balancing forces. On the basis of the above mentioned facts it is possible to give the definition of Newton's first law in a more general form. If no force is acting upon a body or if two balancing forces are acting upon such a body, the body will preserve the state of relative rest or the state of uniform rectilinear motion until some non-balancing force begin acting upon such a body.

The same law enables us to assert that if a body is in the state of relative rest or it is in the state of uniform rectilinear motion. This is possible either in the case when no force acts upon the body or balancing forces act upon it. If too much emphasis is given to this definition of the law it may appear a little ambiguous. Why is it possible that under the same condition a body can be in two states either at rest or in uniform rectilinear motion ?

However, this ambiguity is only an apparent one. If a body is at rest at certain time and at that instant the conditions are such that the given body will continue in one state only that is the state of relative rest.

If a body is in motion at a certain time t and its velocity is equal to v and at the same instant conditions are such that it continue in only one state that is the state of uniform rectilinear motion, with speed V.

It is very important for the teachers to understand and then to explain to their pupils that inertia manifests itself easily when no force acts upon the body. In this case the phenomenon of inertia is easily observed. Besides inertia also exists and when force is acting upon a body. This idea should be supported by examples and experiments. According to the methods suggested, the introduction of individual points of this topic should be done in a different way than it is stipulated in the syllabus These methods prescribe that the teacher should introduce the concept of fiction and deal with this question only after he has discussed the laws of motion. The measurement of inertia is a measurement of inertness when balancing forces act upon a body. This order is suggested due to the necessity of giving pupils a practical method to measure the force of friction.

This can be done only on the basis of Newton's first law. If we want to measure the force of sliding friction of a wooden block moving along the surface of a table it is sufficient to apply a force on to the block and make the body move uniformly, But according to Newton's law the body can move uniformly only when balancing forces act upon it In this case two forces are acting upon the body—the traction force and the force of friction. These two forces are balanced, *i.e* , numerically the force of friction must be equal to the tractive force.

$$F_{friction}=F_{traction}.$$

Thus we find the following simple procedure. To measure a sliding frictional force it is sufficient to fasten a dynamometer to the moving body, to set this body in uniform motion and measure the force of traction with the dynamometer.

When the teacher introduces the topic 'friction', he should begin with the analysis of some examples from pupils' own experience. These examples must show that the frictional force of motion is invariably a force which prevents motion and therefore its direction is always opposite to the direction of motion of the moving bodies. After this analysis the teacher should again show the experiment of the rolling ball along the inclined plane, drawing pupils' attention to the fact that it is friction which causes the change in the speed of the ball

Then the teacher explains the method of measuring sliding frictional force which was described above and then he discusses the dependence of the frictional

force on the weight of the body, or to be more precise, on the force of the normal pressure of the body He should also discuss whether the frictional force depends on the surface area of the body provided normal pressure is the same. Normally, the discussion of this topic does not cause any difficulty and therefore we shall not discuss it in detail.

Quantitative problems

1. An aeroplane is flying at a speed of 1200 km. per hour Give the speed in per second

2. A train is moving uniformly at a speed of 60 km per hour from one town to another. The distance between the towns is 100 km Find the time which is necessary for the train to cover this distance.

3. An aeroplane's speed is 900 km per hour, the duration of the flight is 5 hour. What distance will be covered by the plane ?

4. The distance between Moscow and Delhi is 5230 km Air India International Boeing 707 flies at a speed of 750 km. How long will it take to fly from Delhi to Moscow ?

5. What was the average speed of a parachutist if it took him five minutes to reach the surface of the earth from a height of one and a half kilometres ?

6. How long will it take for a raft to cover a distance of 15 kilometre if the speed of the current is 5 per second provided the raft is floating in the direction of the current ?

7. A motor car is moving at a speed of 72 kilometres per hour. Give its speed in metres per second.

8 The first orbiting of the earth by Yuri Gagarin in a spaceship was accomplished in 89.1 minutes The average speed of the spaceship was 28,000 kilometres per hour. Find the distance covered by the spaceship

9 The world flying speed record set up in 1951 by the Soviet flier Mosolv was 2388 kilometres per hour. Give the speed in metre per second

10. On the way to home from school, a girl counted 11,00 steps The distance was covered by her in sixteen minutes. Taking, that the average length of a step was 96 centimetres, find the speed at which she walked

11 For the first time in history the distance from the earth to the moon was covered by a Soviet Space rocket in 34 hours. This distance is 3,70,000 kilometres Find the average speed of the rocket

12. A horse is uniformly pulling a cart on a horizontal road. The tractive force is 48 kgw Find the coefficient of friction if the weight of the cart is 400 kgmt.

13. A locomotive is uniformly pulling a freight train on a horizontal railway. The weight of the train is 2,400 kg wt The tractive force of the locomotive is 7,200 kg wt. Find the coefficient of friction.

14. Determine the force of friction between the steel brake and the wheel of the locomotive if the pressure of the brake is 2,000 kg wt. The friction coefficient is 0.14

15 The coefficient of friction of a cart moving along a side road is 0.16. What tractive force must be developed by the bull on a horizontal section of the road to pull uniformly a cart weighing 400 kg wt

II. Qualitative problems.

1. Why is it easier to jump over a bridge if one is running ?
2. Why is it dangerous to cross a street in front of a vehicle when it is close to you ?
3. Why does a driver slow down when there is a turn ?
4. Give examples where inertia is a useful phenomenon and when it is harmful.
5. When bringing his bus to a stop the driver disconnects the engine from the driving wheels well before the stop and thus saves fuel. Why ?
6. How will you explain the dropping of mercury column while shaking the medical thermometer ?
7. If one is running away from somebody who is pursuing him, he makes swift side movements when his pursuer is ready to catch him. What is the reason of doing so ?
8. What would happen to a rider if his horse stumbles suddenly ?
9. Why do rain drops fall down when a wet coat is shaken.
10 Why do some wagons of a train get disconnected when the engine driver starts the engine abruptly. In which case is such disconnection more probable; if the train is loaded or if it is unloaded ?

III. Qualitative problems of friction

1. What do the incision on the lips of the vice and pliers serve ?
2. Sometimes when a cart moves down a hill one of its wheels is fixed to prevent rotation Why ?
3. Why does the pull of a transmission belt from one pulley to another increase the friction between the belt and the pulley ?
4. Why does a side road become slippery after rain ?
5. Why is it not safe to drive down a sloping side road after a rain ?
6. Why is it difficult to write with a pencil on glass, and paraffin paper ?
7. Why is screw sometimes soaked before it is driven into wood ?

8. Why does a starched shirt become dirty less quickly than an unstarched shirt ?

9. Why does a loaded lorry swerve less after rain than an unloaded lorry ?

10. Does one put in the same effort when he lifts some weight or drags it on the floor.

Action and Reaction.

1. On the table there is a weight of 5 kg. wt. With what force does the table act on the weight ?

2. A wooden block floats on the surface of water. The weight of the block is 5 kg wt What are the forces of action and reaction on it ? Where are they applied ?

3. How do action and reaction manifest themselves when a boy jumps from a boat on to the shore ?

4. To what are the forces of action and reaction applied when a hammer strikes on the head of nails ?

5. Why is it difficult for a fireman to hold the hose from which the stream of water is coming out at a high pressure ?

6. An adult normally has 32 teeth. How many teeth take part in the act of softening the food if one tooth is extracted ?

Experimental problems.

1. Put a trolley on a table and put a block on it. Put another block besides the trolley on the table. Softly set the trolley in motion. In relation to which body will the block on the carriage be in motion and against which body will it be in state of relative rest ?

2. On the demonstration table put a moving platform of 70-80 centimetres in length and on this platform put a carriage provided with a winding mechanism. Put a block on the table near this platform. Set the platform in motion. In which state is the carriage with respect to the platform and with respect to the block ? In which state is the platform with respect to the block ?

3. This arrangement can also be used in solving another problem Set the carriage in motion in one direction and simultaneously move the platform in the opposite direction at the same speed In which state is the carriage with respect to the block ?

4. Take a wooden rod of 70-80 centimetres in length and wrap the upper part of the rod with a load belt of 4-5 centimetres in width Knock the table with the handle of the rod. How will you explain the downward motion of the load belt along the rod ?

5. Place an inclined plane on the table At the base of the inclined plane, place a horse-shoe magnet. Show the direction of the motion of a steel ball—once

with the magnet and another time without it. What accounts for the change in the direction of the motion of the steel ball ?

6. Place a pile of match boxes on the demonstration table On the upper box place a glass of water. With the help of a ruler swiftly strike out one match box after another from under the glass. How can you explain the observed effect ?

7. Place a trolley on the demonstration table. On the trolley place a block provided with weights. With the help of a thread connect this block to the demonstrated dynamometer and set the block in uniform motion. Why the reading of the dynamometer is more at the first instant than at the next ?

8. On the table put three wooden blocks with hooks and connect these blocks with one another. To the first block connect the demonstration dynamometer and measure the force which moves uniformly all the three blocks. Then put these blocks one above the other and move them uniformly with the help of a dynamometer. Why are the readings of the dynamometer the same in both cases ?

9. Fix a glass funnel in the ring of a stand.

To this funnel connect a rubber tube which is connected with a glass tube bent at right angles. Put a cork in the end of the tube. Pour some water into the funnel and place below it a metal pan. Take the cork out of the tube. Why is the tube deflected from its original position when the water leaks out ?

10. On the table put segner's wheel and put water into the funnel How will you explain the rotation of the wheel ?

THE TOPICAL PLAN OF THE FIRST CHAPTER OF THE COURSE OF PHYSICS FOR CLASS VII:

Mechanical Motion. —17 *periods*

No of lessons	Date	Topic	Method of Work	Demonstration	Home task
1.		Introductory talk—concept of relative motion and rest.	Talk accompanied by demonstration.		
2.		Translatory and rotatory motion.	Talk and demonstration.		
3.		Measuring time	Talk and demonstration.		
4.		Uniform Rectilinear motion,	Talk and demonstration,		

No. of lessons	Date	Topic	Method of Work	Demonstration	Home task
5.		Solving problems on uniform motion.	Talk and demonstration.		
6.		Non-uniform rectilinear motion average speed	Talk and demonstration.		
7.		Solving problems on non-uniform motion			
8.		Newton's first Law	Talk and demonstration.		
9.		Intertia; solving problems.			
12.		Solving problems on friction			
13.		Pupils work	Independent work the pupils under the teacher's supervision.		
14.		Methods for increasing the force of friction	Talk and demonstration.		
15.		Action and Reaction	Talk and demonstration.		
16.		Solving problems—revision of the topic.			
17.		Written test on the topic			

The aim of the lesson : To give an idea of the relative rest and motion.

VII. The detailed Plans of all the Lessons of the Topic.

Lesson No. 1

Topic : Mechanical motion.

The plan of the introductory talk

I. The content of the physics course for class VII.

II. The significance of the physics course for class VII for understanding mechanical and thermal phenomena, nature and technology.

III. Presentation of the new topic :

(*a*) Introduction of the concept of mechanical motion of bodies on the basis of the discussion of mechanical motions from the experience of the pupils

(*b*) Demonstration of mechanical motion

(*c*) Demonstration of the relative motion.

(*d*) Discussion of relative motion and rest on the examples from pupils' every day experience.

(*e*) Conditions determining relative motion and relative rest.

(*f*) Classification of motion by its trajectory : rectilinear and curvilinear, (Demonstration).

IV. Retention of the new material by the method of group revision.

QUESTIONS :

1. What is mechanical motion of bodies ?
2. Why are any motion and rest relative?
3. When is a body in relative motion?
4. When is a body in relative rest?
5. Why is the following statement incorrect : "The body A is in motion"?
6. What motion is called rectilinear?
7. What motion is called curvilinear?

V. Home task.

Lesson No. 2

Topic : Translatory and rotatory motion.

The aim : To clarify the specific features of translatory and rotatory motion.

I. Questions to pupils

The following questions should be put to pupils during this part of the lesson.

1 What is mechanical motion?
2. Why are any motion and rest, relative?
3. Examples of relative motion in nature and every day life.
4 Show relative motion and rest by performing experiments.
5. What is the classification of mechanical motion by its trajectory?
6. To show experiments on rectilinear and curvilinear motion.

II. Presentation of new material

1. The link between the topic of the previous lesson and the present one.
2 Writing down the topic of the lesson on the classboard.
3. Demonstration of translatory motion.

4. Demonstration of the specific features of translatory motion of different bodies.
5 Demonstration of rotatory motion of different bodies.
6. Demonstration of the specific features of rotatory motion of different bodies.

III. Retention of the new material .

Questions for work :

1. What is the classification of mechanical motion, according to the type of motion ?
2. What motion is called translatory motion?
3. Why is translatory motion regarded as the simplest type of motion ?
4. Give examples of translatory motion.
5. What motion is called rotatory motion?
6. Give examples of rotatory motion.

IV. Home task.

Lesson No. 3

Topic : Measuring time.

The aim : To make pupils understand that any study of physical process involves measurement of time. To clarify the principle of measuring time.

I. Questions to pupils:

1. Why are motion and rest relative ?
2. What are the signs of translatory motion?
3. Give examples of curvilinear translatory motion
4. What are the signs of rotatory motion?
5. Give examples of a body which is in both translatory and rotatory motion at the same time.
6. Why is the following statement incorrect from the point of view of physics ?
   "The bicycle is at rest "

II. The link between the previous lesson and the present lesson. Writing down on the blackboard the topic of the lesson

III. Presentation of new material .

1 All phenomenon and processes in nature take place during certain interval of time.
2. Phenomena of longer and shorter duration.
3. The need for accurate measurement of time.
4. Demonstration of oscillatory motion.
5. The peculiarity of any oscillatory motion.
6. Measuring time by using oscillatory motion.

7. The unit of time.
8. Time measuring devices.

IV. Retention.

QUESTIONS :

1. What are the peculiarities of oscillatory motion ?
2. What is the unit of time ?
3. What is the correlation between different units of time ?
4. About time measuring devices.

V. Home task.

Lesson No. 4

Topic : Uniform rectilinear motion.

Aim: To explain to pupils the peculiarities of uniform motion and the method of calculating the speed of uniform motion.

I. Questions to pupils.

1. By what criteria is mechanical motion classified?
2. What units of time do you know ?
3. Solving problems on the correlation of the different units of time
4. Why is the state of motion or rest relative?
5. By what criterion do we establish whether a body is at relative motion or at relative rest.

II. The link between the previous lesson and the present one.

III. Presentation of new material.

1. Classification of mechanical motion in terms of rate of motion.
2. Demonstration of the uniform and rectilinear motion.
3. Definition of uniform motion.
4. Speed of uniform motion.
5. Calculation of the speed of uniform motion.
6. Unit of speed

IV. Retention

1. Solving problems on calculating speed of uniform motion.
2. Solving problems on converting the value of speed into different units.

V. Home task

Lesson No. 5

Topic : Uniform rectilinear motion.

Aim : Teaching pupils how to solve problems on uniform motion.

I. Questions to pupils.

1. What is the classification of mechanical motion in terms of rate of motion?

2. What motion is called uniform motion?
3. What is the peculiarity of the speed of uniform motion?
4 How can you calculate the speed of uniform motion?
5. Solving problems on calculating the speed of uniform motion.

II. The link between the previous lesson and the present one.

III. Presentation of new material.

1 Calculation of the distance covered in uniform motion.
2. Calculation of the period of time during which a body moves uniformly.

IV. Retention

Solving problems on uniform motion.

V. Home task.

Lesson No. 6

Topic : Non Uniform motion.

Aim : To clerify the nature of non-uniform motion and introduce the concept of the average speed of non-uniform motion.

I. Question to pupils on :

1. The definition of uniform motion.
2. Formula of uniform motion.
3. The unit of speed of uniform motion.
4. The units of time and the correlation between them.
5. Solving problems of uniform motion.

II. The link between the previous lesson and the present one.

III. Presentation of new material.

1. Demonstration of non-uniform motion.
2. Definition of non-uniform motion.
3. The average speed of non-uniform motion.

IV. Retention.

Solving problems on the average speed of non-uniform motion.

I. Questions to pupils :

1. What motion is called non-uniform motion ?
2. What motion is called uniform motion ?
3. About the peculiarity of the speed of uniform motion.
4. Formula of uniform motion.
5. Calculation of the average speed of non-uniform motion.
6. What is the essence of the idea of relative motion and rest ?
7. Solving problems on the average speed of non-uniform motion.

II. The link between the previous lesson and the present one.

III. Presentation of new material.

1. The formula for calculating the distance covered by a body in non-uniform motion.

2. Formula of the time of non-uniform motion.
3. What is the difference between the average speed of non-uniform motion and the speed of uniform motion.

IV. Retention.

Solving problems on non-uniform motion.

Lesson No. 8

Topic : Newton's first law.

Aim : To clarify the essence of Newton's first law.

I. The link between the previous lessons and the present one.

II. Presentation of the new material.

1. The history of the problem.
2. Demonstration of the motion of a metal ball on the inclined plane with horizontal surfaces of different materials.
3. The conclusion drawn from this demonstration.
4. Definition of Newton's first law.
5. Interpretation of Newton's first law.
6. Examples for proving the validity of Newton's first law.

III. Retention

1. How is Newton's first law stated ?
2. Why can we not perform direct experiments proving the validity of Newton's first law.
3. In which case, can a body be in uniform rectilinear motion in accordance with Newton's first law ?

IV. Home task.

Lesson No. 9

Topic : Inertia.

Aim : To clarify the concept of inertia and how to measure it.

I. Questions to pupils .

1. How is Newton's first law stated ?
2. What is the interpretation of the fact that Newton's first law is applicable in either of the cases, when the body is at rest or is in uniform rectilinear motion ?
3. Solving problems on uniform and non-uniform motion
4. How can you classify mechanical motion in terms of the speed of motion ?

II. The link between the previous lesson and the present one.

III. Presentation of new material.

1. Demonstration of uniform and rectilinear motion under the action of balancing forces,

2. Demonstration of the relative rest under the action of balancing forces.
3. Summing up Newton's first law.
4. Demonstration of the inertia of rest of a body.
5. Demonstration of the inertia of motion of a body.
6. Demonstration of mass as the measure of inertia of bodies.

IV. Retention

Solving problems on inertia of bodies.

V. Home task.

Lesson No. 10

Topic : The force of friction.

Aim : To clarify the significance and nature of friction.

I. Questions to pupils.

1. What is Newton's first Law of motion ?
2. What type of two forces are called balancing forces ?
3. What is inertia of a body ?
4. What is the measure of inertia of a body ?
5. Solving problems of uniform and non-uniform motion.
6. Solving problems on inertia.

II. The link between the previous lesson and the present one.

III. Presentation of new material.

1. Cause of change in speed of bodies.
2. Demonstration of the motion of a ball on the inclined plane with different bases.
3. The nature of the force of sliding friction
4. Demonstration of measuring the force of friction.

IV. Retention.

1. What causes friction ?
2. Why in uniform motion the force of friction is equal to the force of traction ?
3. What happens when under the influence of the force of friction and the force of traction the body is in uniform motion ?
4. Which one is greater : the weight of a body or force of sliding friction ?
5. Now can you measure the force of sliding friction ?

V. Home task.

Lesson No. 11

Topic : Coefficient of friction.

Aim : To clarify the concept of the coefficient of friction.

I. Questions to pupils.

1. About the laws of uniform motion

2. How is the average speed of non-uniform motion measured ?
3 How is the Newton's first law stated ?
4 What is the force of sliding friction ?
5 In solving problems on inertia
6. Solving problems on inertia.

II. The link between the previous lesson and the present one.

III. Presentation of the new material.

1. Demonstration of the dependence of the force of friction on the weight of body.
2. The concept of the coefficient of friction
3. The non-dependence of the force of friction on the area of the surfaces in contact.
4. The dependence of the coefficient of friction on the nature of the surfaces in contact.
5. Rolling friction.
6. Static friction.

IV. Retention

Solving problems on friction.

V. Home task.

Lesson No. 12

Topic : Friction and the coefficient of friction.

Aim : To teach pupils how to solve problems on friction.

I. Questions to pupils.

1. What causes friction?
2. What is the device to determine the coefficient of friction ?
3. Does the force of sliding friction depend on the area of the surfaces in contact ?
4 Solving problems on uniform and non-uniform motion.
5. Solving problems on friction.

II. The link between the previous lesson and the present one.

III. Introduction of new material.

1. Rolling friction.
2 Demonstration of the relationship between the force of sliding friction and the force of rolling friction.
3. Demonstration on static friction.
4. Solving problems on friction.

IV. Retention

1. In which cases does the force of friction manifest itself ?

2. What is the relationship between the force of sliding friction and the force of rolling friction, if all the other conditions are the same ?
3. What is the force of static friction ?
4 How can you measure the force of static friction ?
5. How can you explain the stability of bodies at rest ?
6. Solving qualitative problems on friction

V. Home task.

Lesson No. 13

Topic : Friction.

Ami : To teach pupils how to measure the force of friction experimentally.

I Teachers introductory talk on the methods and the technique of the laboratory work (accompanied by demonstration of the apparatus which the pupils are to use independently).

II. At the end of the talk, the teacher shows on the class-board the form in which the results of the measurement are to be recorded At the same time pupils distribute the sets of instruments

III. During the laboratory work the teacher supervises the pupils' independent work and renders help to individual group of pupils

IV. Three-four minutes before the bell goes, the pupils on duty collect the devices and submit the experimental results.

V. Discussion of the results obtained by the individual groups of pupils.

VI. Home task.

Lesson No. 14

Topic · Application of friction in technology.

Aim : To clarify the existence of the following two types of friction in technology. Useful friction and harmful friction.

I. Questions to pupils.

1 What types of friction do you know ?
2 How can you measure the force of static friction ?
3. How can you measure the force of rolling friction ?
4 Which one is greater of the two the force of sliding friction or the force of rolling friction, other conditions being equal ?
5. Which one is greater: the force of sliding friction or the force of static friction, other conditions being equal ?
6. Solving problems on inertia
7. Solving problems on friction.
8. Solving problems on motion,

II. Linking previous knowledge with the new topic.

III. Presentation of the new material

1. Harmful friction in technology · its demonstration
2. Methods of decreasing harmful friction
3. Useful friction in technology
4. Methods of increasing useful friction.

IV. Retention.

1. Give examples of harmful friction in technology.
2. What methods do you know for decreasing harmful friction ?
3. Give examples of useful friction in technology
4. What methods do you know for increasing useful friction ?
5. Solving qualitative problems on friction.

V. Home work.

Lesson No. 15

Topic : Action and reaction.

Aim : To clarify the elementary concept of Newton's third law.

I Questions to pupils

1. What is the definition of Newton's first law ?
2. Where does an action of force manifest itself ?
3. What is the meaning of the statement : "A force is acting upon a body".
4. What types of forces do you know ?

II. Linking previous knowledge to the new topic.

III. Presentation of the new material

1. Two types of interaction of forces
   (*a*) Demonstration of interaction of bodies, when they are not displaced.
   (*b*) Demonstration of interaction of bodies which causes displacement of these bodies.
2. The general definition of the force
3. Demonstration of action and reaction of bodies
4. The significance of Newton's third law.
5. Demonstrations for proving the validity of Newton's third law.
6. Demonstration of reaction of the out-flowing liquid on the tube.

IV. Retention.

Solving qualitative and experimental problems on Newton's third law,

V, Home task,

Lesson No. 16

Topic : Revision of material of the first chapter.

Aim : To prepare pupils for written tests on the topic

I. 1. The plan of revising the material.
2. Uniform and non-uniform motion.
3. Solving problems on motion
4 Newton's first law—Inertia of bodies.
5. Solving problems on inertia.
6 Types of friction and methods of measuring the force of sliding friction, rolling friction, static friction and coefficient of friction
7. Solving problems on friction.
8 Action and reaction
9. Solving qualitative problems on Newton's third law.

II. Home task.
To prepare for a written test.

Lesson No. 17

Topic : Written test on the first chapter.

Aim : To check up the pupils for the understanding of physics for class VII.

Each varient of the written test should include only problems and should not contain any theoretical questions. Each paper should contain three problems:

(1) A problem on motion (quantitative).
(2) A problem on friction (quantitative).
(3) A problem on inertia or on Newton's third law (quantitative)

To achieve a better method of check-up, a teacher should have six varients of the same test, each varient being of the same difficult level.

SOME EXAMPLES OF THE NOTES OF LESSONS OF THE FIRST CHAPTER

Mechanical Motion

Lesson No 1

Introductory Talk

The course of physics for class VII is very interesting and at the same time very complex. According to the syllabus, pupils are to study two large sections of the physics course *viz*, mechanics and heat. The word 'mechanics' originates from the Greek word 'Mechanikos' which means a machine or device It is well

known that as early as the time of the ancient Egyptians, Greeks, Romans and others, various machines were used for construction and military purposes. As early as in the third century B C , Archemedes constructed a number of war machines which were used for defending the city of Syracuse The study of the interaction between different parts of the machines, lever, wheels and the like, led to the appearance of the branch of science which is called mechanics. Machines play an important part in the development of technology in science and in man's everyday life. Machines can successfully perform the work what was formerly performed by man with hard manual labour One can understand this only if one knows the science of mechanics, the basic principles of which are used in designing, and developing of all up-to-date machines Today, we begin this interesting and important section of the course of physics To ensure best learning of the course of physics you will have different types of lessons You will have lessons in which the teacher will introduce the new material and accompany his talk with demonstration, lessons devoted to solving physical problems and finally you will have excursions to plants and factories. Each student, therefore, should have three notebooks in physics :

1 A notebook for writing down various data related to the lesson.
2 A notebook for solving problems in the class and at home
3 A note book for laboratory work

The first topic of the section of the mechanics, is the topic of *Mechanical Motion.* Write down the name of the topic in your notebooks.

Presentation of the New Material

Motion is a common phenomenon which we observe every day. In the streets we see various kinds of transport in action; motor cars, buses, bicycles and people moving on foot. In rivers we can observe the motion of the water, the motion of boats and ships. We can also observe the motion of the moon around the earth and the motion of artificial satellites. Again, the earth itself revolves round the Sun.

Question to pupils

1. Give examples of mechanical motion. From everyday life we can produce mechanical motion by experiment Let us consider more attentively some examples of mechanical motion Let us assume that we are on a boat floating in a quiet river and do not hear the sounds of the working engine. If the windows of your cabin are pulled up, then, what would be your answer to the question . What is the state in which we are ? Are we moving or are we at rest ? Your answer would be that you and all the other objects on the boat, e.g , the electric lamp on the table, the book and the steamer itself are at rest But if you pull down the windows and see the shores of the river, what would your answer be to the same question ? In

this case we would compare the position of our steamer with respect to some objects on the shore, the trees, the houses, etc. Hence, we can draw the following conclusion.

To determine the state of motion or of rest of an object, it is necessary to have some other object in addition to that whose state is being determined. If the distance between some object on the shore and the steamer does not change with time, in this case we can say that with respect to the shores the steamer is at rest. If the distance between the steamer and the individual building on the shore changes with time, we can say that the steamer is in motion with respect to this building. Hence, we can say that the steamer is in motion with respect to the river-shore, the train with respect to the railway track, the motor car on the highway with respect to the trees along the highway and so on Let us clarify the concept of relative motion and the rest by performing some experiments. Let us place a carriage on a demonstration table and a block on the carriage. Beside the carriage let us place another block on the table. What is the state of this carriage with respect to the other block on the table ? Let us mark the distance between the carriage and this block. Then let us push the carriage. What can you say now about the state of the carriage with respect to the reference body (the block on the table)? The distance between the carriage and this block will change. Consequently, the carriage is in the state of motion with respect to this block. What can you say about the state of motion with respect to this block? What can you say about the state of block which is on the carriage ? The block on the carriage is also in motion with respect to the body of reference. What can you say about the state of the block on the carriage with respect to the carriage itself ? The block is in the state of rest because with the lapse of time the position of the block, with respect to the carriage, does not change. Thus, you see that the same body is in state of motion with respect to some bodies and is at rest with respect to other bodies. Let us consider another experiment. Let us place two similar model cars with winding mechanism. By the side of the model motor cars place an arrow on some stand Let us set both the models in motion. In what states are the models with respect to the reference body (the arrow on the stand) ? The motor cars are in motion with respect to the arrow. Why are the motor cars in the state of motion with respect to the arrow ? They are in motion with respect to the arrow because with the lapse of time, the distance between the motor cars and the arrow changes (increases). What can you say about the state of one of the model cars with respect to the other ? The first model is at rest with respect to the other Why are they at rest ? Because, with the lapse of time, the distance between the models has not changed What conclusions can be drawn from these examples and experiments ?

1. Mechanical motion is the displacement of one body with respect to another, which is taken as a reference body.

2. Both motion and rest are relative. Give examples of relative motion and rest. The bus is in motion with respect to the earth. The bus is in motion

with respect to the bus stop The moon is in motion with respect to the earth. Artificial satellites are in motion with respect to the earth. Why the following statement is incorrect ? "Motor car is moving". There is no indication of the reference body in the statement. All the varieties of mechanical motion observed in nature and technology can be classified according to the trajectories of bodies. The trajectory of a body is the trace left by the body in motion. In some cases the trace of a moving body can be seen easily. You might have observed the trace of a jet aeroplane in the form of a white line against the blue background of the sky. You might have seen also the trace of a rocket in the night sky The line, which appears when a piece of chalk moves on the blackboard, is the trajectory of the motion of the chalk. Let us perform an experiment which enables us to obtain the trajectory of the motion of an individual ball which has earlier been soaked in red ink.

What have you observed in this demonstration ? In one case the trajectory of the moving ball is a straight line and in another case it is a curved line Consequently, all the types of mechanical motion can be classified by their trajectories into rectilinear and curvilinear What type of motion is rectilinear ? What types motion is called curvilinear motion ? Curvilinear motion is a motion whose trajectory is a curved line.

Home task.

Lesson No. 8

Topic · Newton's first law.

In our previous lessons we have discussed uniform rectilinear motion. However, analysing this type of motion we did not consider in detail, the way in which bodies can be set in uniform motion. Consequently, the topic of today's lesson will be . "Conditions under which bodies can be set in uniform motion." Speaking on the different types of mechanical motion we emphasize that the most common form of motion is non-uniform motion, over a short portion of a distance We shall discuss some from every day life. You must have noticed many times that drivers switch off the engine while approaching the traffic lights. However, the automobiles continue in motion for sometime with the speed decreasing gradually, and finally stop completely How can you explain this whole phenomenon ? Take another example Approaching the bus-stops, the driver of a bus switches off the engine but the bus continues moving with its speed gradually decreasing, before it finally stops moving Let us perform the following demonstration which will help us to understand why all these happen Let us have an inclined chute on the table and observe the motion of a ball, which is rolled down from the same height Here the horizontal portion of the ball's track must have

different surfaces For this purpose let us place different types of surfaces . sand, cloth, wood and glass at the base of the inclined plane. Each time, whenever we roll down the ball we shall mark the distance covered by the ball before it stops completely. What do you observe ? In which case does the ball cover the longest distance ? The ball covers the longest distance when it moves on glass. Why does the ball cover the longest distance when it moves on glass ? The ball covers the longest distance on glass because in this case the ball experiences the least force of resistance against motion What would happen to a ball rolling on an horizontal plane, if there were no forces of resistance ? Moving on glass, the ball covered the longest distance because the glass resisted the movement of the ball only to a very little extent. However small the resistance of the glass and the air is, it affects the motion of the ball, and it finally stops. In fact these forces of resistance are the forces due to resistance of the air and the forces of friction We can say consequently, that if no force acts upon a body, the body continues in motion at the same speed and the motion is rectilinear Let us have one more experiment On the table there is a block which is at relative rest Why is this body at relative rest ? Because no force acts upon this body. Let us see what happens to the position of this body if some force starts acting upon it. In such case the body starts moving. Now the question arises, till what moment will the body continue to be in relative rest ? It will continue at relative rest until some force acts upon it, *i.e.*, until some other body acts upon it So, now we can give a more accurate formulation of this law of nature Everybody continues in uniform rectilinear motion or in the state of relative rest until some force starts acting upon it. Let us solve a few problems by implementing this law. A body was moving at some speed and the speed decreased What happened during the change in the speed of motion ? Evidently some force has acted upon this body. This conclusion follows from the first law which says that a body can change its speed if some force acts upon it.

Another problem : The body was at rest and then it started moving What has caused its motion ? Some force must have acted upon the body, because if no force had acted upon this body, the body would have continued in its state of relative rest. This law is called the law of inertia All objects in nature possess this property. We can say consequently that a motor car continues moving even after its engine was switched off because of inertia, that the ball which rolls down on an inclined plane continues its motion along the horizontal portion of the track because of inertia. Bodies are at relative rest because they possess inertia. Hence all bodies which are in motion possess inertia of motion and all bodies at rest possess inertia of rest. Give examples of inertia of motion and inertia of rest. Let us have a few experiments clarifying the concept of inertia of bodies Suppose we have to

fix a handle into a hammer head and for that insert the one end of the handle into the whole of the head and strike hard the other end against the table top.

What is the explanation of the performance of this action ? When the hammer head and the handle are moving down, the hammer head and the handle possess inertia of motion, i e , they have the property to continue in motion. When you knock the handle on the table, the motion of the handle stops under the action of a force whereas the hammer head continues moving downward for some time because of inertia and the handle fits into the hammer head.

Let us have another demonstration (pulling out a sheet of paper from under a glass tumbler filled with water) Why does the glass tumbler not topple ? Before the pulling began, the sheet of paper and the glass with water were at rest and consequently possessed inertia of rest, i *e* , the property to continue in the state of rest. Because the pulling was done quickly, the time of action was very small and so the glass tumbler continued at rest because of inertia.

Lesson No. 9

Topic : Inertia of bodies—balancing forces.

Introduction to the new material :

In our last lesson we got acquainted with the essence of Newton's first law or the law of inertia. Under this law a body continues in uniform rectilinear motion or at rest until it is acted upon by some force. At first sight, this law does not seem very precise It says that if no force acts upon a body, the body can be either at relative rest or in uniform rectilinear motion.

If at an instant a body is at rest and from this moment the action of all forces upon this body stops, this body will be in one state only, the state of relative rest until this body is acted upon by some force which will move it out of the state of rest. If at an instant, a body is moving with some speed V, and at this very moment the action of all forces on this body stops, this body will continue in one state only, the state of uniform rectilinear motion.

The speed V will remain the same until some force acts on the body (this should be accompanied by demonstrations and conclusions drawn) . Thus from this law it follows that a body can be in the state of uniform rectilinear motion only, if no force acts upon it. Is it so in reality ? Analysing the type of motion we said that at separate portion of the track we can observe uniform motion of different types of transport · motor cars, ships, trains, etc , but it is evident that in such cases the engines of the vehicles develop some tractive force. Let us see if these examples contradict the law of inertia. Let us have two demonstrations :

Demonstration No 1

On the table there is a block with two books. In what state is this block with respect to the table ? It is at relative rest. In this case no force is acting upon the block. Let us apply two equal but opposite forces to this block acting along the same straight line Let us see if the state of relative rest of this block changes under the action of these two forces What have you seen ? The block did not change its state of relative rest. Such two forces, which are equal in magnitude and act on the same body in the opposite directions along the same straight line, are called balancing forces You have seen from this experiment that two balancing forces do not change the state of relative rest. The resultant action of these two forces is equal to zero, just as in mathematics $(+5)+(-5)$ gives zero. Hence, we can draw the following conclusion. A body continues in the state of relative rest in the two cases—if no force is acting on the body or if two balancing forces are acting upon a body Let us analyse the second demonstration The motion of a steel ball in the tube filled with viscous liquid is familiar to you. You saw it when we discussed uniform motion What forces are acting on the ball which is in uniform motion There are two forces—the force of gravity of the ball and the force of viscous resistance These two forces are directed along the same straight line and they are in opposite directions (a sketch on the classboard) What conclusion can we draw from this demonstration ? Evidently, these forces are equal but acting in opposite directions, these forces are balancing forces Hence a body can move uniformly along a straight line in the following two cases

1 If no force acts upon a body
2 If balancing forces act upon a body.

Now we can answer the question· why some means of transport can move uniformly over a short portion of the track only ? Here, the following two forces are acting on the moving vehicle:

1. The tractive force of the engine.
2. The total force of resistance

What can you say about these two forces if they set the vehicle in uniform motion? These two forces must be balancing forces, *i.e*, F ( ) motion=—F ( ) resistance

Let us solve the following problems.

1. The tractive force of the automobile which is moving uniformly in a straight line is 100 kg wt. What is the magnitude of the total force of resistance ? It is equal to 100 kg wt because if the body moves uniformly, the force of resistance and tractive force must be mutually balancing forces.

2. The total force of resistance in case of a steamer moving uniformly along the river in a straight line is 300 kg wt. What is the magnitude of the tractive force of the engine ? It is 300 kg wt due to the same reasons as in problem above.

On the basis of these two demonstrations, we can give a more elaborate interpretation of Newton's first law. Every body continues in uniform rectilinear motion or relative rest as long as no force is acting on this body or as long as it is acted upon by balancing forces This is to be formulated as follows

Every body continues in uniform rectilinear motion or relative rest until it is acted upon by non-balancing forces. Non-balancing forces are the two forces (or more) which are not equal in magnitude or do not act upon a body in the same straight line in opposite directions. In our last lesson we said that inertia is a property which is possessed by every object of nature Let us now consider if this property manifests itself equally from the quantitative point of view in different bodies Let us consider the demonstration which we performed in the lesson—the motion of a ball on inclined plane For this purpose, we shall take different balls, roll them down from the same height and observe their motion on the same horizontal surface Pay attention to the path which is covered by the balls on the horizontal portion before they stop Which of the balls covered the longest path? Is it the heaviest ball? We can draw the following conclusion The property to continue in rectilinear motion is characteristic of all objects However, objects with more mass possess this property to a greater degree Last time we performed an experiment on inertia of rest using a glass tumbler filled with water. If we repeat this experiment but without any water in the glass tumbler what will happen ? Then you will see that the glass tumbler breaks. Evidently, both the glass tumblers possess inertia of rest but the glass tumbler containing water has more mass, and consequently, it possesses more inertia.

Let us solve the following problems :

1 Which railway car can be set in motion with less effort—loaded one or the empty one—provided the portion of the railway track is horizontal? Both the loaded car and the empty possess inertia of rest. However, the car of more mass has more inertia.

2. Two railway wagons, one empty and the other loaded, move along a horizontal path at the same speed. Which of the wagons is more difficult to stop. The loaded one; because it has more inertia. These demonstrations and examples enable us to draw the following conclusions The mass of a body is the measure of inertia of the body. Bodies with larger mass possess more inertia than bodies with small masses. In turn, the greater the weight of body the larger is its mass, *i.e.*, the mass of a body is proportional to its weight The mass of a body is one of the important characteristics of any object.

Demonstration of inertia in vehicles and interpretation of these demonstrations.

Home task

List of all Demonstrations in Mechanical Motion for the class VII course

1 Mechanical motion as a change in the position of a body in relation to another body on the assumption that the latter is at rest.

2. All types of mechanical motion classified according to their trajectories—rectilinear and curvilinear

3. Some examples of the translatory motion of bodies.
   (*a*) Motion of a motor car model.
   (*b*) Motion of a sliding drawer of a table
   (*c*) Upward and downward motion of the load on a crane model or a fixed pulley.

4 The characteristic features of any translatory motion of a body.

5 Examples of rotatory motion .
   (*a*) A turbine model.
   (*b*) A centrifugal machine.
   (*c*) An electric motor model

6. The characteristic features of any rotatory motion.

7. Uniform rectilinear motion.
   (*a*) With the help of a glass tube filled with viscous liquid and a metal ball.
   (*b*) With the help of a trolley.

8. Non-uniform motion.

9. Means of measuring time. Any periodic process used for measuring time.
   (*a*) Show the periodic motion of the simple pendulum
   (*b*) Show the periodic motion of the twisted horizontal pendulum.
   (*b*) Show the working of the tuning fork
   (*d*) Show the working of the clock mechanism.

10. The manifestation of inertia of bodies in motion
   (*a*) An example of the moving trolley showing how inertia manifests itself.

11. The inertia of bodies at rest manifesting itself

   (*a*) Show the inertia of bodies at rest by pulling out a sheet of paper kept under a glass filled with water.
   (*b*) The same with the metal disc knocked out from the pile of discs.
   (*c*) In the experiment with a trolley.
   (*d*) The mass of a body as the measure of its inertia. Repeat the experiment described in (b) with wodden and metal disc.

12 The state of relative rest not being disturbed if two equal and opposite rectilinear forces act upon a body at rest.

13. Continuation of the state of uniform motions of a body if two equal and opposite rectilinear forces act upon it.
14. Existence of friction while bodies are in motion
    (*a*) The motion of a roller.
    (*b*) The motion of a ball
    (*c*) The motion of a block.
15. Method of measuring sliding friction.
16 Peculiarity of sliding frictional force.
    (*a*) Sliding frictional force is always less than the weight of a body.
    (*b*) Frictional force does not depend on the area of the frictional surfaces.
17 Measuring rolling frictional force.
18 Under the same conditions, the force due to rolling friction is less than the force due to sliding friction.
19 Measuring static friction
20. Technique of decreasing harmful friction in technology.
    (*a*) Dependence of sliding frictional force on the quality of the finish of the sliding surfaces.
    (*b*) Technique of decreasing frictional force by replacing sliding friction by rolling friction.
    (*c*) Various kinds of ball-bearings and roller-bearings.
21. Action and reaction (qualitative)
    (*a*) With two interacting elastic bodies.
    (*b*) Interactions of two springs in a horizontal plane.
22. Action and reaction (quantitative)
    (*a*) With demonstration spring balances.
    (*b*) Between a solid body and a liquid, when the solid body is immersed in liquid.

CHAPTER II

Composition of Forces

Equilibrium of forces

1. *Significance of this chapter*

This relatively small chapter of the course of physics for class VII is of great polytechnical significance. Pupils normally assimilate it without much difficulty if the methods of conducting each lesson are clear-cut and logical This chapter is important from the point of view of learning because when pupils study it, they acquire a more profound understanding of one of the most important concepts in physics—the concept of force.

The knowledge relevant to this chapter acquired by the pupils earlier is expanded and clarified. A good understanding of the concept of force under this topic, facilitate successful learning of the following topics in the course of physics for class VII: work and energy, simple machines etc. While dealing with this topic, we acquaint pupils with the composition of forces, the concept of the centre of gravity of the body, types of equilibrium and the stability of bodies Among these concepts, the concepts of force and the centre of gravity of bodies are most difficult

All theoretical points of the topic are of great polytechnical significance and consequently, the teacher can show what role these concepts play in understanding the fundamentals of modern technology.

Let us take up, for example, the principle of composition of forces In fact, one has to deal with these concepts in different branches of science several forces act on the same body Here, we need to find out the action of the resultant force Thus when a motor car is in motion, it is acted upon by the tractive force of the engine, the force of friction, the force of air resistance, gravity etc. A railway bridge is acted upon by the force of gravity, the resistance force of the support, the weight of a train moving along the bridge and other forces. Consequently, in order to be able to construct buildings, bridges, machine-tools and machines, it is necessary to know well the laws of composition of forces.

The concept of the centre of gravity of bodies is also very important. If the centre of gravity of the wheel of a railway carriage does not coincide with its axis, an accident may take place Equally important is to calculate precisely the location of the centre of gravity of a turbine wheel, of the shafts of various machines and machine tools which perform a great number of revolutions in a unit of time. Even small errors in determining the centre of gravity of these bodies may cause breakage.

II. *The content of the chapter according to the syllabus.*

According to the syllabus, this chapter comprises the following points :

1 Composition of two forces acting in the same straight line, the resultant force
2 The centre of gravity
3 Types of equilibrium of bodies having an axis of rotation
4. Equilibrium of bodies resting on a base
5 Laboratory work No 2 .
"Determination of the centre of gravity of flat bodies".

III. *Analysis of the most important concepts*

The concept of force as well as the concept of mass, energy and work is one of the principal concepts of physics. It is essential primarily for the teacher and also for the students to understand correctly and profoundly what is meant by this fundamental concept. We first come across this concept while studying mechanics At later stages, this concept is used when molecular phenomena are studied. the surface tension of liquids, its viscosity, etc. We come across concept of force when electricity is studied, *viz* , the action of the electric and magnetic fields on charged particles (electrons, protons, ions)

Force is the measure of the interaction of bodies. It appears in the process of interaction between two bodies In other words, force manifests itself in the interaction of bodies

Also, it is necessary to understand well, the two possible manifestations of force—appearance of acceleration and origin of deformation. The most complete definition of the force is the following .

The force is a vector characterising interaction of bodies which causes acceleration deformation or both deformation and acceleration. How do the various actions of force manifest themselves ? If a body is acted upon by a force which is perpendicular to the surface of the body without causing any displacement of this body, the result of the action of the force is deformation of the body, *viz.* a change in the shape or the volume of the body. Deformation is also caused by a force, if the magnitude of the force acting on the body is smaller than the force of static friction. In all these cases when a force causes acceleration in the motion of a body, there is a partial

deformation of it In the case of absolutely rigid bodies the force will be causing acceleration in the absolutely rigid body

The action of any force on a body is determined by the following three factors

1. The magnitude of the force
2. The direction of the force.
3. The point of application of the force.

The magnitude of the force is determined by Newton's second law. The equation F =m. a shows the relationship between the change in the speed, the inert mass of the body *m* on which the force *F* is acting.

Hence, we can express the magnitude of the force

$$F=m\frac{dv}{dt} \text{ or } F=m.a.$$

It is easy to demonstrate by simple experiments that change in any one of the characteristics of force : magnitude, the direction, and the point of application causes a change in the action of the force. In statics, it is convenient to show forces as straight lines in different directions whose lengths denote the magnitude of the force given on scale Thus if a force F of 3 kg wt., which is horizontal and applied at a point, acts upon the body A, this force may be expressed as shown in Fig. 1

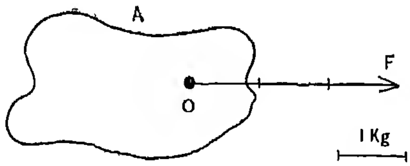


Fig. 1

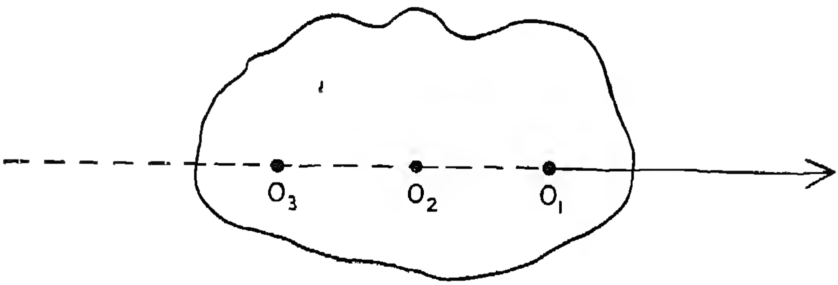


Fig. 2

The graphical method of expressing forces is widely used in statics and in solving various problems

Two forces regarded as vectors are considered equal in their action, if all the three characteristics of the force identical, i e., if the forces are equal in magnitude and have the same direction and are applied at the same point

The composition of force is of great polytechnical significance It accounts for the fact that in practice, in everyday work and in nature we observe the simultaneous action of several forces on the same body. In such cases we cannot give an answer to the question, what will be the resultant action of this force on the body. However, we can easily establish the nature of the action of one force on the body. Thus, if we put a block on a table and a force is acting normally on this block without causing its displacement, we can say that the action of the force results in the deformation of the body.

If in a similar case the direction of the force is parallel to the surface of the table and this force exceeds the force of static friction, we state that the action of the force will result in the acceleration of the motion of the block. Consequently, the significance of the physical action of the composition of forces, consists in replacing several forces acting on the same body by one force equal in action to several forces It also enables one to establish the nature of the action of the resultant force on the same body.

If a body is acted upon by two forces inclined to each other, the magnitude and the direction of the resultant is determined by the parallelogram law The resultant of two forces acting at an angle is represented by the diagonal of the parallelgoram constructed out of these forces Consequently, forces as well as some other vectors (velocity, acceleration etc.) are added up according to the parallelogram law, *i.e* , geometrically.

Hence to find the resultant of two forces acting on a body at an angle, it is necessary to construct a parallelogram with these forces as its sides and to draw a diagonal from the point of the application of these forces. Fig. 3. If the acting forces are expressed by the vectors, the lengths of which on an accepted scale represent the magnitudes of these forces, the length and the direction of the diagonal will be the magnitude and the direction of the resultant force.

If the forces are acting in one straight line in one direction Fig. 4 the resultant is equal to the sum of the forces acting in the same direction.

If the forces are acting along the same straight line but in opposite directions, the resultant is equal to the difference of the two forces acting along the same straight line in the direction of the greater force Fig 5,

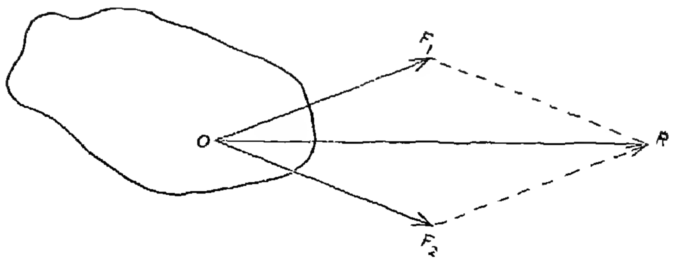
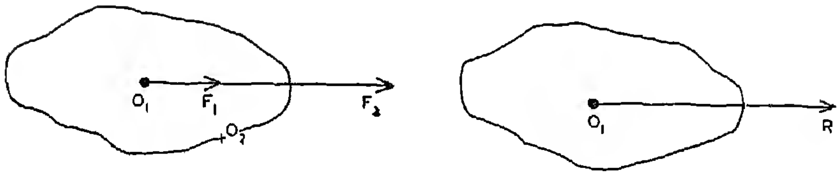
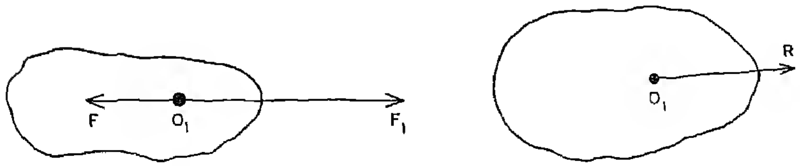


Fig 3



a *b*

Fig. 4



a *b*

Fig. 5

If more than two forces are acting on a body, the resultant can be calculated by adding up the forces consecutively. First we should find the resultant $R_{1,2}$ of the first two forces F_1 and F_2 Then the force F_3 should be added to the resultant force $R_{1,2}$ and the IV resultant force $R_{1,2,3}$ be found, etc.

Methods of studying the concept of force

The formation and development of the concept of force in the school course of physics is a long complex process This should be first introduced in class VI and then gradually developed and enriched

While learning physics, pupils already have an idea of force associated only with muscular efforts In class VI, the studies of physics begin with an analysis of a particular type of force—the force of gravity. Proceeding from the phenomena familiar to pupils, *i e*, falling of bodies, stretching a thread by some load and the pressure exerted by a body on a surface because of the force of gravity, the teacher introduces the concept of the force of gravity Pupils' acquaintance with the action of gravitational forces and the necessity to prepare them for the study of hydrostatics requires informing pupils about some elementary data of the force of gravity and the weight of a body at the very first stages. Dealing with the topic "force and its measurement" the teacher develops and expands the concept of force. Pupils get acquainted with some particular examples of the manifestation of force when deformations and displacements take place It is imperative that transition from the so-called everyday concept of force to the scientific concept of force should be carried out A spring balance can be used in introducing the idea of the magnitude of force and the point of application of the force. The teacher should emphasize that force may not act only vertically as in the case of the force of gravity but in any direction, for example . the tractive force of a horse, a tractor, a motor car.

Studying Archimede's law, pupils also learn that two forces may be applied to a body—the weight and the buoyancy of a liquid or a gas Here pupils meet with a particular case of composition of forces acting vertically along the same straight line in opposite directions

The first topic of the physics course in class VII "Mechanical motion" contain a more elaborate concept of force. Discussing the law of inertia, the teacher introduces the concept of the balancing forces as equal and opposite forces applied to the same body and acting along the same straight line Later, we again deal with these balancing forces while discussing the method of measuring the force of sliding friction Thus we acquaint pupils with a particular case of composition of two forces directed along the same straight line Again, in this topic, we analyse the law of inertia which serves as a basis for the dynamic interpretation of the force as the cause of change in the speed of a body. In the physics course for class VII

we do not introduce the concept of acceleration of motion or Newton's second law Consequently, it is not possible to introduce the concept of force as a cause of the acceleration of the motion of bodies. However, by discussing Newton's first law in this aspect, pupils are prepared for a successful study of the laws of dynamics at the second stage. They will understand well that if the resultant of all the forces acting upon a body is not equal to zero the body will move with an acceleration, the magnitude of which is proportional to the resultant force.

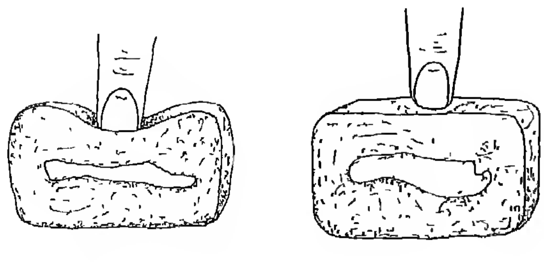
Thus under the plan given, some concrete examples are used in the presentation of all the three types of forces dealt within mechanics (the force of gravitation for the system: the body—and the earth, elasticity and friction) caused by the interaction of bodies Besides, pupils are told of the elements of force and its various mechanical effects : pressure on the support, the stretching of a thread, change in the speed etc. All this should be taken into account by the teacher when he begins introducing this topic. Everything about force that was learnt by pupils in the physics course of class VI as well as in the first topic in class VII, should be revised by pupils under the guidance of the teacher, while proceeding further, the teacher should extend and develop this knowledge so that the pupils could form a clear understanding of this important fundamental concept of modern physics. Undoubtedly, the pedagogical effort connected with assimilation of this topic depends on the way of the discussion of the concept of force in the course of physics of class VI and presenting the first topic of the physics course of class VII. As a result of the revision and getting a more profound and systematic knowledge of force, pupils should understand the following points concerning the concept of force :

1. Force appears in the process of interaction of bodies (at least two bodies). This point should be developed proceeding from the elementary knowledge of Newton's third law introduced in the first topic.

2 *Types of forces and their nature*—Here, we include the force of gravity, and friction. The force of gravity is the force with which bodies are attracted by the earth. This force manifests itself in the pressure which bodies exert on their supports or in the stretching of a thread from which a body is suspended The force of gravity or the weight of a body can be measured with a spring balance.

The force of elasticity emerges in bodies when their shape or volume is changed This force acts upon the crossection of a body and is directed against the deforming force. What is the nature of these forces ? When deformation is caused by pressure, the distance between the molecules decreases, the forces of repulsion grow more quickly than the forces of attraction, repulsion overcomes the attraction between molecules and the body resists pressure. Conversely, when deformation is caused by stretching, the distance between the molecules increases the forces of repulsion decrease more quickly than the forces of attraction, attraction overcomes the repulsion of the molecules and the body resists stretching

Why should we draw teacher's attention to the forces of elasticity when a body is deformed ? This is necessary to make clear that a force emerges in the process of the interaction of two bodies It turns out that when bodies are in immediate contact, they act on each other only if they experience deformation. A thread is acting on a carriage with some force because it is stretched (deformed), a locomotive pushes a wagon because its springs are pressed and so on. From the magnitude of these deformations we determine the forces with which bodies act on one another Hence, when we say that force emerges in the process of interaction between bodies, this is to say that force emerges in the process of mutual deformation of interacting bodies However, in everyday life and technology, these deformations are not always observable to the naked eye. This is particularly true of the interaction between solid massive bodies. These deformations are not observable only because they are small but they always exist Thus, if a rubber band thread is tied to a carriage and then pulled by hand, the carriage will move Observing this interaction of bodies, we easily detect the stretching of the rubber band (its deformation) but we fail to detect the deformation of the carriage. In reality, the carriage is also deformed but this deformation is much smaller and cannot be detected visually Why does deformation take place at all, when bodies interact ? Deformations take place because different parts of the same body move differently If all the parts of a body moved equally in the same way the body would preserve its original shape, *i e.*, it would remain undeformed. Let us clarify this by the following example. Let us take a soft pencil eraser (Fig. No. 6 a). When the eraser is pressed with a finger, it moves and the fingert effected the upper layers of the eraser whereas the layers nearer to the table are no displaces by the action of the finger and remain stationary. Because of this the eraser changes its shape The movement of the finger, when it presses the eraser, causes a change in the mutual arrangement of the individual parts of the body and in the shape of the body and deformation takes place In the process of deformation, the rubber act with some force on the bodies which are in contact. To demonstrate it let us put a small lead shot into the depression formed by the finger and then remove the finger. (Figure No. 6b). The shot will move up and consequently, we can' say that the elastic force acts on the lead shot. If a spring is suspended from a stand and a weight of 2 kgwt. is attached to the loose end of the spring. the spring will be deformed (stretched). Consequently, some elastic force is acting



a *Fig.* 6 *b*

on this spring. The weight of 2 kg produces, in this case, the force of deformation. Consequently, these two forces act along the same straight line but in opposite directions Since the system is in a state of relative rest, these two forces must be equal according to Newton's first law, *i e*, the elastic force due to deformation must be equal to the deforming force. This is used in measuring the elastic force produced during deformation. When bodies are in immediate contact, we observe the emergence of forces produced during the deformation These are the forces of friction. We dealt in detail with the nature of these forces when analysing the first topic and shall not therefore discuss them here.

3 *The characteristics of a force*

Proceeding from the properties of force with which students are already acquainted, it is essential to show that any force irrespective of its nature has three characteristics :

(*i*) Magnitude

(*ii*) Direction

(*iii*) Point of application

Simple experiments should be used for clarifying these points to students and teaching them how to express these forces graphically.

4. The action of a force depends on all the three characteristics of it. It is possible to prove this by very simple demonstrations. Let us put to pupils the following question Does the action of the force depend on the magnitude of the force ? First, let the students speak and then give an answer to this question on the basis of demonstration. Then we put the following question· Does the action of the force depend on the direction of the force, other conditions being same? (i.e., if the magnitude and the point of application remain the same). The teacher should show the second demonstration.

Finally, the teacher should put the following question Does the action of the force depend on the point of application, other conditions being the same ? Now we can draw the general conclusion that the action of the force is determined if all the three characteristics are given (the magnitude, the direction and the point of application). Consequently, if even one of these characteristics is changed, the action of the force changes as well.

5. *Composition of forces*

Here we discuss only one particular case of composition of forces, *viz* the composition of forces acting along the same straight line. At the beginning of the discussion it is advisable to analyse those cases in technology when two forces are

acting in the same straight line on the same body. Then the teacher should proceed to the cases of composition of forces which are familiar to pupils, *viz.*, uniform motion of a body when friction is present (demonstration of the uniform motion of a ball in a viscous liquid). These experiments should be accompanied by sketches indicating the forces acting on the body. Then pupils should be reminded of another case of composition of forces acting along the same straight line with which they are acquainted. This is the action of forces on a body immersed in a liquid. In this case the following two forces act on the same body along one straight line in the opposite directions. The force of gravity acting vertically downwards and the force due to. Archimede's thrust acting vertically upward. Then the teacher should pass over to the composition of the two forces acting along the same straight line in the same direction. After this demonstration, the teacher should give the definition of the resultant force as a single force equivalent to the given forces in its action. From the concept of the resultant force and the data supplied by the experiment, the teacher gives the rule for composition of two forces acting along the same straight line in the same direction. Problems should be solved by pupils on the basis of this rule. The result of the experiment should be formulated not only orally but the teacher should show that this can be done also by graphical method of expressing forces as vector quantities. The magnitude of a force can be shown as a line of a certain length if some units of length is chosen to be regarded as a unit of force. The direction of the force is shown by an arrow in this straight line while the point of application is shown as a point at the beginning of this line. The following stage in the presentation of the material is the discussion of the composition of three forces acting along one straight line in the same direction. The same arrangement can be used which was used for determining the resultant of the two forces. Finally pupils should be shown experiments to prove that this rule is valid not only for the forces of gravity acting vertically downwards but also for any three forces acting in any direction. The following demonstration can be used for the purpose :

One end of the spring should be fixed to a stand on the foot of which a massive body should be placed. The loose end of the spring should be connected to a thread which should go over a fixed pulley clamped to another stand. Another massive body should be placed on the base of the second stand. Arrange both the stands so that the springs should be horizontal. Then to the loose end of the thread, attach two weights of 100 g and 200 g. Mark off the distance to which the spring was stretched under the action of the two forces. Then take off both weights and suspend one weight of 300 g and again mark the increase in length. Compare the results of both experiments and see that the stretching caused by the two weights is equal to that caused by one weight. Consequently

the weight of 300 g is the resultant of the two weights of 100 g and 200 g acting along a straight line in the same direction

6. *Composition of forces acting along a straight line in opposite directions*

The question should be put to pupils How can we find the resultant of two forces acting along the same straight line in opposite directions ? The teacher gives pupils a simple numerical problem, and asks them to speak on this problem Then the answers are verified by the results of a demonstration. On the basis of result the following rule is formulated .

The resultant of two forces acting along the same straight line in opposite directions is equal to their difference and acts along the same straight line in the direction of the bigger force. (The point of application can be located at any point in the line of the action of the force) Then some problems should be solved and accompanied by their graphical illustration (with the help of vectors). Then the teacher should go back to the concept of the balancing force introduced earlier, the concept of inertia and the formulation of Newton's first law For this purpose, we examine a particular case of composition of two forces acting along the same straight line in opposite directions when these two forces are equal in magnitude. We perform the same demonstration (but with equal forces) which shows that the resultant of these two forces is equal to zero. Hence, it follows that balancing forces can be defined as two forces acting on the same body, the resultant of which is zero. Consequently, the property of inertia can now be formulated in the following way: A body continues in uniform and rectilinear motion or in the state of relative rest if it is not acted upon by any force or it is acted on by a system of forces the resultant of which is equal to zero We can also elaborate on the concept of non-balancing forces introduced earlier. Two or more forces, the resultant of which is different from zero, are called non-balancing forces

Finally, we can formulate differently Newton's first law. A body continues in uniform rectilinear motion or in the state of relative rest until this body is acted upon by a force or a system of forces, the resultant of which is different from zero While concluding of the discussion of this sub-topic—'the composition of forces', it is necessary to show an experiment where a body is acted upon by two forces inclined at an angle. It will be remembered that this frequently takes place in practice and in this case the resultant force will be smaller than the sum of component forces, but greater than their difference.

7. *The centre of gravity of a body*

The fact that pupils do not know the composition of parallel forces and rule of moment for bodies having an axis of rotation does not allow the teacher to make use of the analytical method of presentation of the material in discussing

this question. Therefore, all explanations should be based on experiment. In the beginning of discussion the teacher should introduce the concept of the centre of gravity of a body. Pupils already know that every body has a weight, and the weight is a force with which the body is attracted by the earth, and consequently, the weight of any body is directed vertically downwards. They also know that the weight of any body can be measured in kgwt (in gwt) by a spring balance. The direction of the force due to the weight is known but we draw pupil's attention to the fact that any force, and consequently the weight has three characteristics. Two of these characteristics are already known to pupils, these are the magnitude and the direction What can we say about the third characteristics, the point of application of the force ? Let us divide a body into a great number of parts. Then we can say that the weight of the body is the sum of the weights of all these small portions forming the body. The weight of each such small particle can be expressed by a small vector directed vertically downwards. Consequently all these elementary weights (particles of the body) will be parallel to each other. We shall be able to find the resultant of all these elementary weights It is natural that the magnitude of this resultant weight will be equal to the magnitude of the total weight of this body This force will be directed vertically downwards and the point of application of this resultant will be indicated by the centre of gravity of the body (*Fig. No. 7*).

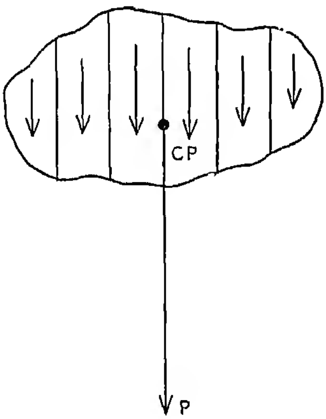


Fig. 7.

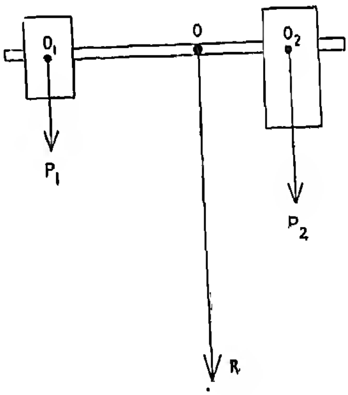


Fig. 8.

Hence the resultant force of gravity act at the centre of gravity of. the body. Then from various examples from technology, it is necessary to emphasise

the importance of finding correctly the centre of gravity of different bodies. The teacher should bear in mind that finding the centre of gravity by the method of composition of two forces is a rather complex task for the pupils. This task is solved rather easily on the basis of the position of parallel forces if the body under examination consists of two parts O_1 and O_2 being connected with a rod. (*Fig. No* 8)

If the mass of the rod is small in comparison with the masses of the parts M_1 and M_2, it may be neglected. Each of the two masses is acted upon by the force of gravity Hence $P_1=M_1g$ and $p_2=M_2g$ Consequently, the task of finding the centre of gravity of a given body comes down to finding the point of application of the resultant of two parallel forces Under the rule of composition of parallel forces acting along the same direction, the point of application of the resultant divides the line connecting the points of application of the parallel forces into portions inversely proportional to the forces. Consequently,

$$\frac{p_1}{p_2} = \frac{00_2}{00_1}. \text{ Hence, } \frac{M_1}{M_2} = \frac{00_2}{!00_1}$$

Consequently, the centre of gravity divides the distance between the two masses, in the inverse ratio of their masses. Hence, the conclusion may be drawn that the centre of gravity of the body constituted of two equal masses, is in the middle of the line connecting these two masses. That is why we can very easily solve the problem of finding the centre of gravity of homogeneous bodies of regular shape.

It is clear that the centre of gravity of a homogeneous rod lies in the middle of it because equal masses are located at the same distance from the middle of the rod. Since any diameter (*Fig. No.* 9) of a homogeneous round disc divides it into two equal and symmetrical halves, the centre of gravity of this disc is located in all of the diameters, *i e*, which is at the point of their intersection, at the geometrical centre of the disc O By similar reasoning, it is possible to find that the centre of gravity of a ball lies at its geometrical centre The centre of gravity of a homogeneous parallelepiped lies at the intersection of its diagonals and so on. If the body is of an irregular shape and if this body is heterogeneous, the calculation in finding the centre of gravity becomes rather difficult and the centre of gravity is more easily found by experiment. If some solid body is suspended from a thread, for instance, a piece of plywood, it will occupy a certain position (*Fig. No.* 10).

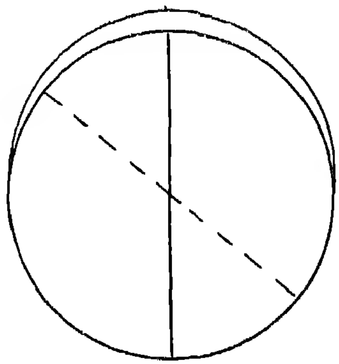


Fig. 9.

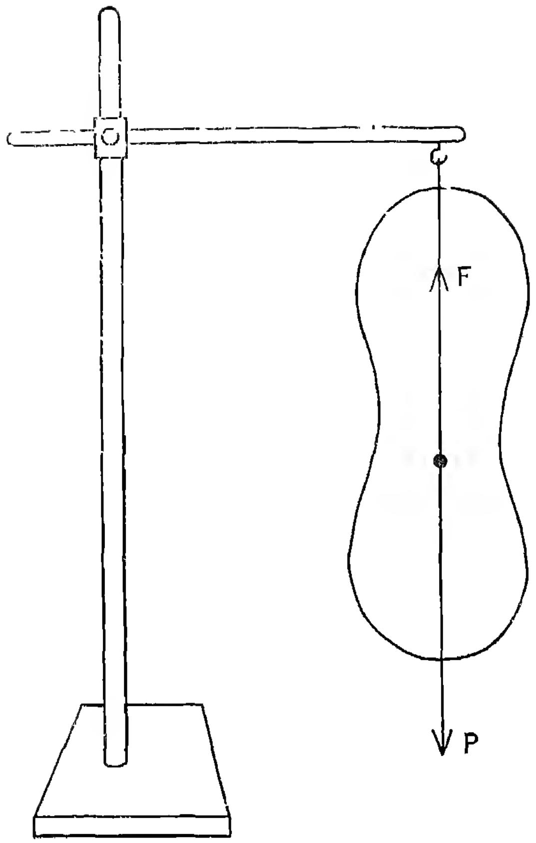


Fig. 10

In this case the body will be affected by two forces, the weight of the body, and the tension of the thread. In these conditions the body is at relative rest and it follows that these two forces are balancing forces because, the force due to tension of the thread and the weight of the body, balance each other. Hence it follows that these forces are not only equal in magnitude but also act along one straight line in opposite directions. Consequently, the centre of gravity of the body is the point through which the resultant force, due to the weight of the body, acts and it also lies in the same vertical straight line. Therefore, drawing a straight line on the piece of the plywood re-presenting a continuation of the thread, we can state that the centre of gravity of the body lies on this straight line If we suspend the same body from different points and draw similar lines on this body, we shall see that all these lines will intersect at one point. If the weight of a

body or its shape is changed the position of the centre of gravity of the body changes as well. Thus, when the stock of fuel is consumed, the centre of gravity of a plane or a rocket changes its position

The following simple demonstration can be used to prove this point. Let us take a block consisting of two halves connected with each other on hinges. Let us attach a thread to the middle of the block and suspend the block by the thread. (One block forms the extension of the other) (*Fig. No.* 11). The centre of gravity will lie on the other axis of the block If this system of blocks is bent (*Fig No* 12),

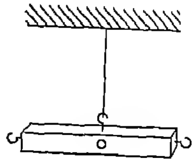


Fig 11.

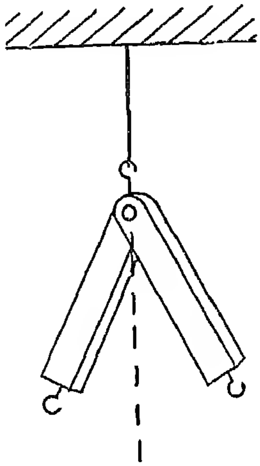


Fig. 12.

the centre of gravity will lie at a point outside the blocks at the bisector of the angle which is formed by the blocks. Consequently, the centre of gravity of some bodies, for example, the above-mentioned combination of two suspended blocks at an angle to each other, or a ring etc., may lie outside the given body. Finally, it is necessary to remember that the centre of gravity of any body does not depend on the position of the body in respect to the earth. The centre of gravity depends solely on the distribution of mass in the body.

8. *Types of equilibrium of bodies*

The conditions of equilibrium of the bodies which turn about a point or an edge of the body, or the base, can be easily explained from

the fundamental principle existing in nature, namely, that the all bodies in nature tend to occupy the position where their potential energy is minimum While discussing in school the types of equilibrium of bodies having an axis of rotation, we introduce a concept of three types of equilibrium : stable, unstable and neutral When the types of equilibrium are studied, the question arises in what positions the body may be stationary in spite of being acted upon by forces The following phenomena are demonstrated and clarified A metal rod is fixed horizontally to the stand. From this rod a ruler is suspended which has three holes,—two at the ends and one in the middle At first the ruler is suspended using the upper hole (*Fig. No.* 13) If the body is deflected to the right or to the left, the moment of the force of gravity will cause its rotation around the point of suspension The ruler will go on oscillating until it occupies the initial position If we attach a plumb line to the axis we shall see that the point of suspension and the centre of gravity of the ruler (the hole in the middle of the ruler) lie on the same straight line. Here, the moment of the force of gravity is equal to zero The weight of the body is balanced by the reaction of the support on the side of the axis and the centre of gravity lies lower than the point of suspension on the same vertical line and this position is the lowest possible position for this body. Hence we can give the following definition. Equilibrium is called stable if the centre of gravity of a body occupies the lowest position. If there is no

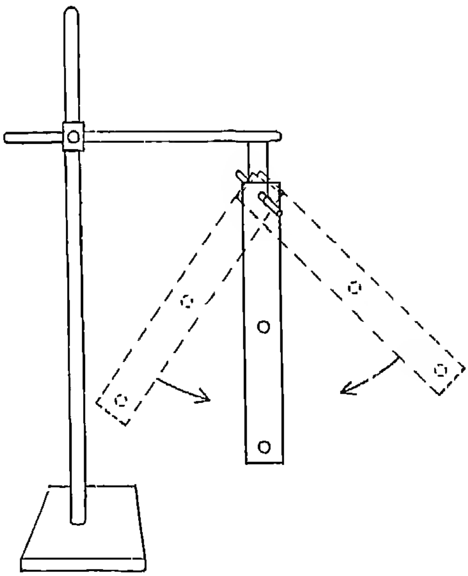


Fig. 13.

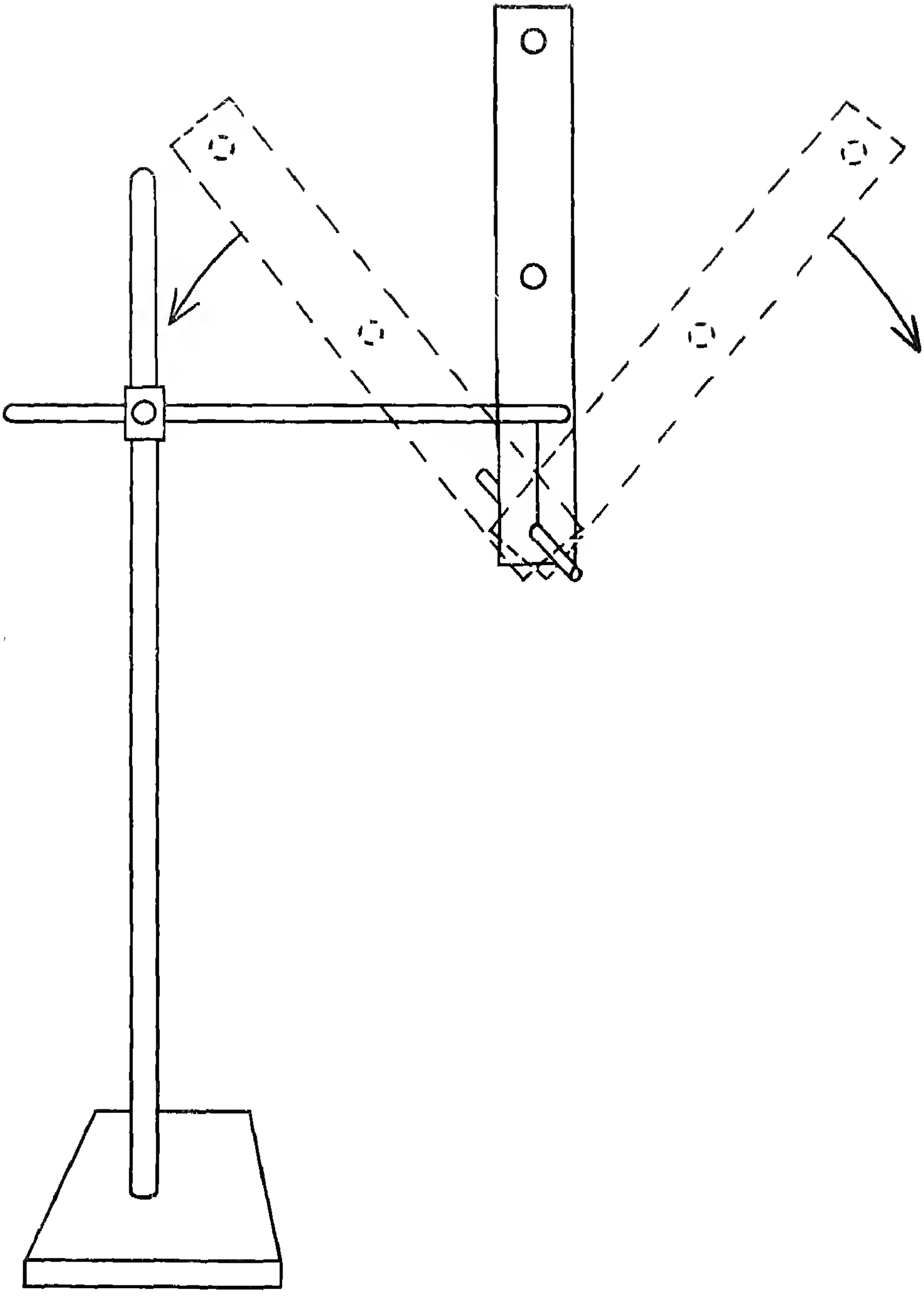


Fig. 14

indication of the centre of gravity of a body, the following principle may be used for finding out the type of equilibrium. The type of equilibrium, where a body, when displaced from the position of equilibrium, regains it again, is called a stable equilibrium. We have explained the return of the body to the position of equilibrium by the effect of the moment of the force of gravity But we could have explained the same phenomenon from the principle of the minimum potential energy of the body. Indeed when we move the ruler out of equilibrium to the right or to the left we can see from Fig 13 that the centre of gravity of the body moves up as compared to the position of the equilibrium and consequently, the potential energy of the body increases according to the formula $E_p = Ph$ where P is the weight of the ruler and h is the distance of the centre of gravity from the earth. Consequently, a body regains equilibrium because each time it was deflected, the body tends to occupy the position of minimum potential energy While presenting this point to pupils we only perform this experiment and give a definition of stable equilibrium. If the ruler is suspended using the lower hole (*Fig No.* 14) we can demonstrate unstable equilibrium Equilibrium is called unstable if the centre of gravity of a body is lowered when this body is deflected from the state of equilibrium. From the principle of minimum potential energy it follows that when a body is disturbed from equilibrium and its centre of gravity is lowered, amount of potential energy of the body is decreased. As the body tends to continue in the state of the minimum potential energy it does not return to the original position in which the body possessed more potential energy. Finally, if we fix the ruler by the hole going through the centre of gravity of the ruler (through the middle part) we shall observe neutral equilibrium (*Fig. No.* 15). Equilibrium is called neutral when a body is displaced and the distance from centre of gravity to the surface of the earth does not change. This arises from the fact that at the same height of the centre of gravity of a body in respect to the earth, there is no change in the amount of the potential energy of the body i e. $W(h) = P. h = \text{const.}$ in respect to the earth. In order that the pupils easily assimilate the material concerning the peculiarities of the types of equilibrium it is necessary to solve a few qualitative and experimental problems which we suggest later. Now we proceed to the discussion of the conditions of stable equilibrium for bodies having an area of support. For this purpose it is necessary to show a demonstration using a parallelepiped formed of planks joined with one another on hinges. The opposite of the parallelepiped are connected with rubber threads and a plumb line is attached to the point of their intersection. The three following cases should be demonstrated by using this parallelepiped.

1. The vertical line coinciding with the plumb line passing through the area of support (*Fig. No.* 16).

2. The vertical line passing through the edge of the base (*Fig. No.* 17).

3. The vertical line falling outside the area of support. (*Fig. No.* 18). The

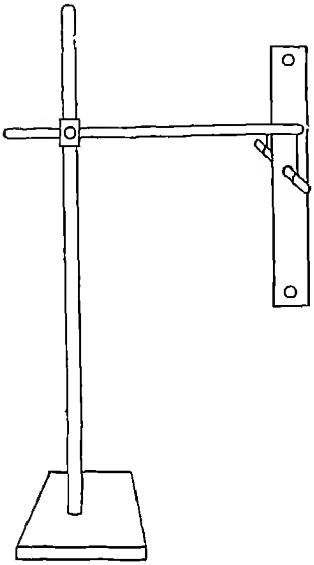


Fig 15.

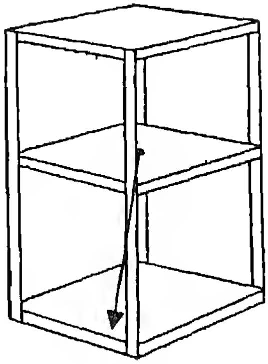


Fig. 16.

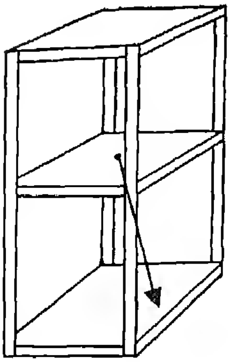


Fig. 17.

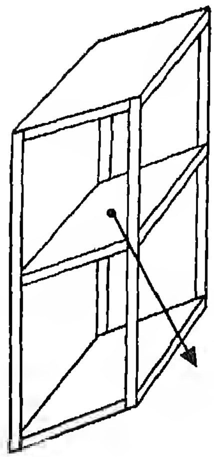


Fig. 18.

following conclusion can be drawn from this demonstration. A body is in stable equilibrium if the vertical line passing through the centre of gravity of the body intersecting the area of support. Then the teacher should show the following demonstration helping to find out the condition of equilibrium depending on the

position of the centre of gravity of a body in respect to the surface of the earth. For this purpose a wooden rectangular parallelepiped can be used Diagonals are drawn on one of the sides. The point of their intersection to which a plumb line is fixed, lies at the same height as the centre of gravity of the parallelepiped Pupils attention should be drawn to the fact that in turning the parallelepiped around its edge, the centre of gravity of the parallelepiped first goes up (stable position), then occupies the highest position (unstable position) and then goes down In the first case the force of gravity returns the body to the initial position; in the second case is the moment of gravity equal to zero. In the third case the body topples over. The limiting angle, beyond which, if the body turned, topples after being over is called the limiting angle of stability. It can be measured by a demonstration protractor (It should be borne in mind that at this angle of inclination the moment of the force of gravity is equal to zero).

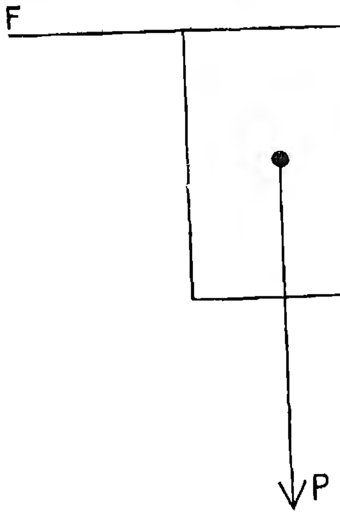


Fig. 19.

Note . In order to make the above demonstration more visible, the parallelepiped can be placed on the edge of a flat board and, to raise the other end of the board at different angles (*Fig* *No.* 20).

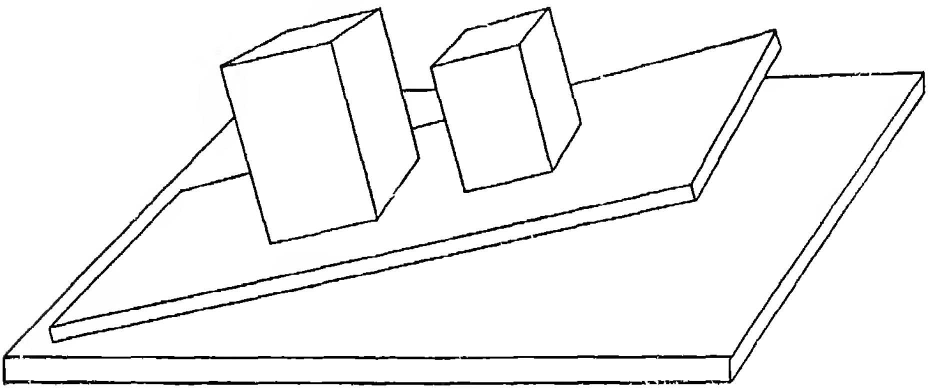


Fig. 20

V. *Problems*

A. *Composition of Forces*

1. Express as vector a force of 3 kgwt acting on a body—horizontally.
2. Express as a vector a force of 2 kgwt acting on a body vertically upward.
3. Express as a vector the weight of a body equal to 5 kgwt.
4. Express as vectors the tractive force of 5 kgwt and the force of friction of 3 kgwt acting on the same body.
5 Express as vectors tractive force and force of friction acting on uniformly moving body if the tractive force is 3 kgwt
6 Express as vector the tractive force and force of friction acting on a uniformly moving body if the force of friction is 5 kgwt
7 Express as vector the forces acting on a body at rest on the top of a table if the weight of the body is 2 kgwt.
8. Express as vector the forces acting on a body at rest if the force of reaction of the table is 5 kgwt.
9 Express as vectors the forces acting on the same body along the same straight line and in the same direction if one force is 3 kgwt and the second is 4 kgwt
10. Express as vectors the forces acting on the same body along the same horizontal straight line in opposite direction if one force is 5 kgwt. and the other is 2 kgwt
11. Express as vectors the forces acting on the same body along the same vertical line if the force directed downward is 8 kgwt. and the upward force is 5 kgwt.
12 Two weights of 100 gwt each, stretch a spring. What is the weight that would cause the stretching of the spring by same length?
13. What is the resultant of the two forces applied to a body at point A and acting in one straight line in opposite direction, if one force is 10 kgwt. and the other 3 kgwt?
14. What is the resultant of the two forces applied to a body at point A (*Fig No.* 21)?

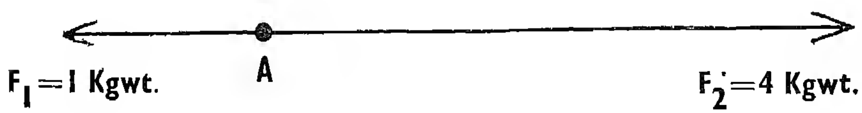


Fig. 21

Fig 22

15 What is the resultant of the three forces applied to a body at point A (Fig. No. 22) ?

16. Is it possible to weigh a body approximately 6 kgwt with two dynamometers each of which has a 4 kgwt limit?

17. Two engines are sometimes used for driving heavy trains, one in front of the train and the other as a booster Find the force of resistance when the train is in uniform motion if the first engine produces the tractive force of 1800 kgwt and the second of 10,000 kgwt.

18. A boy whose weight is 40 kgwt holds a weight of 10 kgwt on his hand. What pressure does he exert on the earth ?

19. Can the resultant of two forces of 4 kgwt and 5 kgwt acting on a body along the same straight line be equal to 2 kgwt, 3 kgwt, 8 kgwt and 10 kgwt ?

20. Three forces of 3 kgwt, 4 kgwt and 5 kgwt, are acting on a body along the same straight line. Can the resultant of these forces be equal to 1,2,3,4,5,6,10,12 and 15 kgwt?

B *Centre of Gravity*

1. Indicate the position of the centre of gravity for each of homogeneous flat bodies (shown in Figure 23).

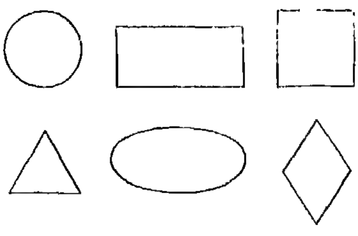


Fig. 23.

2 How is it possible in practice (without calculations) to find the centre of gravity of flat bodies cut of cardboard or plywood?

3 How can you find (roughly) the centre of gravity of a pencil, a pen, a brush, a file and a screw driver?

4, How can you find the middle of a glass tube without measuring its length?

5. The right-hand part of a rod is made of iron, the left-hand part of the same length is made of copper. Draw a picture and indicate the approximate position of the centre of gravity of the rod with a point.

6 When does the centre of gravity of a tall tree occupy a higher position in autumn when the leaves have fallen, or in summer

7. Which of the two similar lorries has a higher centre of gravity in respect of the earth if one of them is loaded with sand and the other is loaded with wood, the weight of which is equal to the weight of the sand?

8. A part 200 centimetres long, was cut of a steel tube. In what direction and by how many centimetres did the centre of gravity of the tube shift?

9 Why does a man bend forward when carrying some load on his back ?

10. Why is it not possible to stand up from a chair without either bending a little forward or bending the feet a little ?

11. Why does a weight attached to the tail of a flat figure imitating a parrot cut of plywood, make it stable?

12 Two buckets (*Fig. No* 24) contain equal quantities of water. Which of them is more stable?

13. Why are the bases of chess figures filled with lead?

14. What is used for increasing the stability of table-lamps, table-clocks and lifting-cranes.

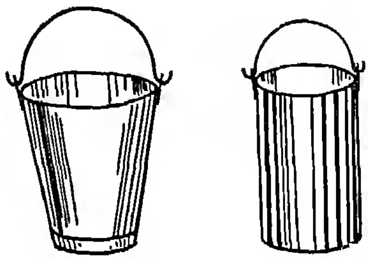
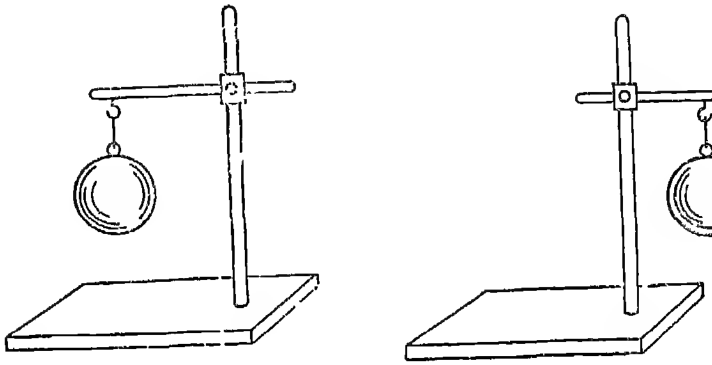


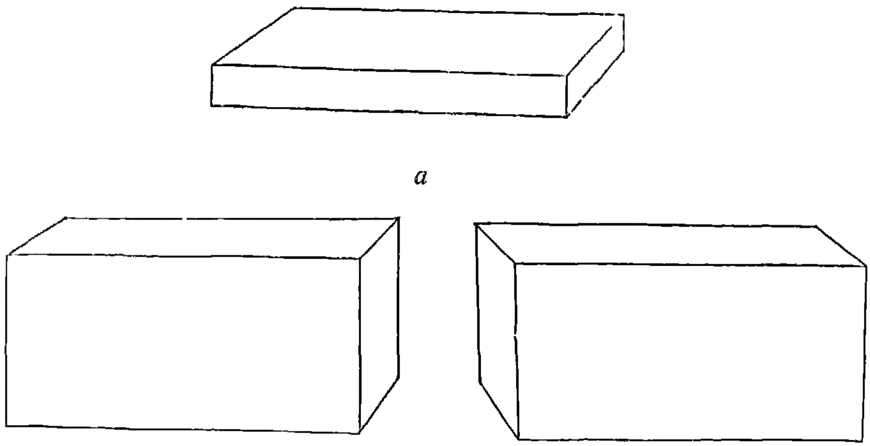
Fig. 24.

15 In which position is the stand with a suspended weight more stable ? (*Fig. No* 25a, b).



a Fig. 25 *b*

16. Figure (26a, b, c) shows a brick in three different positions Which of them is the most stable and the most unstable?



b Fig 26 *c*

17. Why is it not allowed to go standing in an open lorry?
18. Why do ducks and geese waddle when they walk?

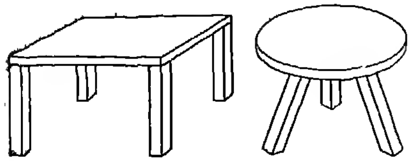


Fig. 27

19. The tables in picture have the same weight. Which of them is the most stable? (Fig. 27)

20 To keep a stick in a vertical position on a finger, one has to move the finger in space. Why ?

V. Topical Plan of the Second Chapter in the Physics Course for Class VII

COMPOSITION OF FORCES; EQUILIBRIUM OF BODIES

Nos. of lessons	Date of the lesson	Topic of the lesson	Method of work	Demonstration	Home work
1.		Characterstics of forces.	Teacher's talk.		
2.		Composition of forces acting in one direction along the same straight line.	Do.		
3.		Composition of forces acting along one straight line in opposite directions	Do.		
4.		Solving problems on composition of forces.			
5.		The centre of gravity of a body.	Pupils' independent work.		
6.		Laboratory work No. 2, "finding the centre of gravity of flat bodies."			
7.		Equilibrium of bodies with the axis of rotation.			
8.		Equilibrium of bodies resting on a support.			

DETAILED PLANS OF ALL LESSONS OF THIS CHAPTER

Lesson No. 1

Topic : Characteristics of force.

Aim : To explain to the pupils that the action of a force is determined if the following characteristics are known :

(*a*) Magnitude of force.
(*b*) Direction of force.
(*c*) Point of application of force.

I. Plan of presentation of new materials·

1. Three types of forces; the force of gravity, the force of elasticity, the force of friction.
2. Manifestation of the action of the force.
3. How do the forces appear?
4. Characteristics of forces—the magnitude, direction and point of application.
5. The action of the force changes, if at least one of its characteristics changes.
6. Graphical representation of forces.

II. Retention.

Questions for the whole class.

1. How do the forces appear?
2. How do the forces manifest themselves?
3. How does the action of a force manifest itself in producing the deformation of a body?
4. How does the action of a force manifest itself in changing the state or speed of a body?
5. Which characteristics of a force do you know?
6. Which two forces do we call equal forces?
7. Solving problems on representing forces with vectors.

III. Home task

Lesson No. 2

Topic : Composition of forces acting along one straight line and in one direction.

Aim : To explain the pupils the concept of the resultant forces

I. Questions to pupils:

1. Which characteristics of forces do you know?
2. Show experimentally that other conditions being the same, the action of the force changes if the point of application of the force changes.
3. Show experimentally that all other conditions being the same, the action of the force changes if the direction of the force changes
4. Show experimentally that all other conditions being the same, the action of the force changes if the magnitude of the force changes.
5. How is Newton's first law formulated?
6. What is the formula for coefficient of friction ?
7. What is inertia?
8. Solving problems on the representation of forces with vectors 20, 21.

II. Link between the previous lesson and the present one

III. Presentation of the new materials.

1. Determining the action of a force on a body is easy if there is only one force acting on a body.
2. Examples from technology of the simultaneous action on a body of several forces—motion of a motor car, a plane, a steamer etc.
3. Examples from physics for the simultaneous action on a body of several forces—the motion of a body along the surface of another body, bodies immersed in a liquid, bodies at rest.
4. Finding the action of the composition of forces
5. The concept of the resultant forces
6. Experimental substantiation of the law of composition of force acting along the same straight line in one direction.
7. Formulation of the law.

IV. Retention.

Solving problems on composition of forces

V. Home task.

Lesson No. 3

Topic : Composition of opposite forces acting along the same straight line.

Aim : To explain to pupils the law of composition of forces and to help them to acquire skills in solving problems

I. Questions to pupils·

1. What is the definition of the law of composition of forces acting along the same straight line in one direction
2. Show experimentally the validity of the law of composition of forces acting along the same straight line in one direction.
3. Solving problems on representing forces as vectors.
4. Solving problems on composition of forces.
5. What is meant by uniform motion?
6. The laws of uniform motion of bodies
7. What is meant by translatory motion?

II. Link between the previous lesson with the present one.

III Presentation of the new material.

1. Analysis of examples from technology illustrating the action of opposite forces along same straight line
2. Analysis of examples from physics illustrating the action on a body of two opposite forces directed along the same straight line (the force of traction and the force of sliding friction, the force due to the weight and the reaction of the support, the force due to the weight and the resultant thrust on account of the displaced liquid
3. Experimental verification of the law of composition of two opposite forces acting along the same straight line.
4. Formulation of the law of composition of forces.

IV. Retention.

Solving problems on composition of forces

V. Home task.

Lesson No. 4

Topic : Solving problems on composition of forces.

Aim : To help pupils to acquire skills in solving problems on composition of forces.

Questions to pupils:

1 What is the formulation of the law of composition of two opposite forces acting on a body along the same straight line?
2 Show experimentally the validity of the law of composition of two opposite forces acting along the same straight line?
3. What is the formulation of the law of composition of two forces acting on a body along the same straight line in one direction?
4 Show experimentally the validity of the law of composition of two forces acting on a body along the same straight line in one direction?
5. Solving problems on composition of forces acting along the same straight line.
6 What is the average speed of non-uniform motion and how can you calculate it?
7. What is inertia of bodies?
8. What is the measure of inertia of bodies?

II. Solving problems on composition of three and more forces acting along the same straight line.

III. Home task.

Lesson No. 5

Topic : The centre of gravity of bodies.

Aim : To explain to pupils the concept of the centre of gravity of a body and its practical applications

I. Questions to pupils:

1. What characteristics of the force do you know?
2. How can you represent the force graphically?
3 The law of composition of forces acting along the same straight line.
4 What is the resultant force?
5. Solving problems on composition of forces

II. Link between the previous lesson and the present one

III. Presentation of the new materials.

1. What is the weight of body?
2. Magnitude and direction of the force due to weight.
3. Every force has three characteristics Consequently the force due to the weight of a body must also have these characteristics.
4. The centre of gravity of a body—the point of application of its weight.
5. The centre of gravity of homogeneous flat bodies.
6. Experimental determination of the centre of gravity of bodies of irregular shape.
7. Principle of determining the centre of gravity of a body.

IV. Retention.

Solving problems on determining the centre of gravity of a body.

Lesson No. 6 Laboratory Work No. 2

Topic : Experimental determination of the centre of gravity of flat bodies.

Aim : To help pupils to acquire skills in determining the centre of gravity of flat bodies.

I. Teacher's introductory talk on the laboratory work.

The teacher should clarify the following points (duration 5-8 minutes).

1. Topic of the laboratory work
2. Aim of the work.
3. Methods of determining the centre of gravity (this part is accompanied by demonstrating the devices with which pupils are to work)
4. Organisation of pupils work in various sub-groups.
5. Contents of pupils report on the laboratory work.

II. Distribution of the sets of devices and material.

III. Execution of the work by pupils

IV. Collecting pupil's reports.

V. Collecting the sets of devices.

VI. Home task.

Lesson No. 7

Topic : Equilibrium of bodies possessing the axis of rotation.

Aim : To explain to pupils conditions under which a body can be stationary in spite of the forces acting on it.

I. Questions to pupils·

1. What is the formulation of Newton's first law?
2. What is inertia of bodies?
3. What is the centre of gravity of bodies?
4. Solving problems on finding the centre of gravity.

II. Link between the previous lesson and the present one.

III. Presentation of the new material.

1. Demonstration of stable equilibrium.
2. Definition of stable equilibrium.
3. Methods of detecting stable equilibrium of bodies possessing axis of rotation.
4. Demonstration of unstable equilibrium
5. Determining unstable equilibrium
6. Methods of detecting unstable equilibrium.
7. Demonstration of neutral equilibrium
8. Determination of neutral equilibrium.
9. Methods of detecting neutral equilibrium.

IV. Retention.

Solving problems on equilibrium of bodies having an axis of rotation.

V. Home work

Lesson No. 8

Topic : Equilibrium of bodies resting on a support.

Aim : To explain to pupils the concept of stability of bodies.

I. Questions to pupils

1. Three types of equilibrium of bodies possessing the axis of rotation.
2. Solving problems on equilibrium of bodies.
3. Solving problems on finding the centre of gravity.

II. Link between the previous lesson and the present one.

III. Presentation of the new material

1. Conditions of stable equilibrium of bodies resting on a support Demonstration.
2. Conditions of unstable equilibrium (demonstration)
3. Dependence of equilibrium of bodies on the position of the centre of gravity in respect to the surface of the earth

IV. Retention.

Solving problems on stability of bodies resting on a support.

V. Home task.

NOTES OF LESSONS

Lesson No. 1

The concept of force is one of the most important concepts in Physics You got acquainted with the concept of force as early as in the course of physics of class VI. The topic of today's lesson is a more elaborate concept of force. Therefore, let us review what we have already studied. In class VI you got acquainted with the concept of the weight of a body.

I. What is the weight of a body?

The weight of a body is the force with which the body is attracted by the earth Let us remember how we can measure the weight of a body The force of the weight can be measured with the help of a spring balance. Every body possesses a definite magnitude of weight Let us remember the direction of the force due to the weight of the body. The weight of any body is directed vertically downwards. Let us try to understand in which way the weight of a body manifests itself The weight of a body manifests itself in producing the pressure on the support or in the stretching of a thread from which the body is suspended (demonstration) Thus we know the following data concerning the force due to the weight.

1 The force due to the weight of a body is caused by the attraction of the bodies by the earth
2. The magnitude of the weight can be calculated with the help of a spring balance.
3. The force due to the weight of any body is directed vertically downwards
4 The force due to the weight of bodies manifests itself in the pressure it exerts on the support or in the stretching of a thread from which it is suspended

II. In class VI you also got acquainted with a second type of force which was called the force of elasticity Let us remember what forces are called in physics elastic forces The force arising in bodies, when they are being deformed, are called elastic forces (demonstration : deformation of a ruler under the action of a force) What is deformation? Deformation is a change in the form of a body or its volume under the action of forces. How can the magnitiude of elastic forces be measured ? It is easy to understand that the magnitude of an elastic force is numerically equal to the deformation of a ruler as we put a weight of 500 grams in the middle of the ruler. Under the influence of this force the ruler bends. What forces act on the ruler? The force of the weight of the load and the elastic force of the ruler What is the direction of these forces? These forces act along the same straight line in opposite directions. What can you say about the magnitude of these forces if the ruler remains at relative rest? These two forces are balancing forces and consequently the elastic forces developed in the bodies are numerically equal to the deforming forces, *i e*, in our experiment an elastic force is developed which is numerically equal to the weight of 400 grams. What is the direction of the elastic forces? To give a correct answer to this question it is sufficient in this experiment to remove the weight from the ruler. As you say the ruler assumed its original shape. Consequently the elastic forces are directed so that the body can assume its original shape or volume.

Summing up what we know of elastic forces, we can say that:

1. Elastic forces arise when bodies are deformed, *i. e*, when they change their shape or volume.
2. Deformation is caused by the interaction of two bodies (in our example of the interaction between the ruler and the weight).
3. The magnitude of the elastic force is determined by the mangitude of the demforming force.

   $F_{clas} = F_{deform}$
4. The elastic force is always directed so that the original shape or volume of the body could be restored.

III. Finally, this year we got acquainted with one more type of force, the force of friction. Let us understand what we know about this force. When does the force of sliding friction arise? This force arises when one body moves on the surface of another body. Consequently, this force is developed when two bodies interact. What is the direction of this force? This force always acts in a direction, opposite to the direction of motion of a body and causes the slowing down of the motion. How can we measure the magnitude of the force of sliding friction?

The force of sliding friction is numerically equal to the tractive force, when bodies are moving uniformly

The force of sliding friction arises when two bodies interact (2) the force of friction is numerically equal to the tractive force when the body is moving uniformly (3) The force of friction is always directed against the speed of the moving body What is then the common feature of any force irrespective of the nature of the force? If we compare the conclusions just drawn, we can establish that there is the following common characteristic of any force.

1. *Any force arises in the process of interaction of bodies* (not fewer than two bodies) Hence the statement that a force acts on a body implies that there is interaction between two bodies
2. The action of a force manifests itself in producing deformation of bodies or in a change in the speed of bodies or in both.
3. Every force is characterised by the magnitude expressed in gwt or kg wt.

4. Every force is characterized by the direction of its action. Let us take two characteristics of forces : magnitude and direction. They seem sufficient for determining the action of the force But in the case of an easily deformable body, by changing the point of application of the force, the body can be either deformed or overturned. You see here that the magnitude and direction of the forces are the same but the action of the forces are different. In the first case, the action of the force manifests itself in causing deformation of the block (in changing its shape), whereas in the second case the body is overturned. What was the difference between these two forces? The difference between these forces is that they are applied to different points of the same body. Hence, we can conclude that any force is characterized by the three properties—(1) magnitude, (2) direction and (3) point of application Consequently, the action of force is determined if all the three characteristics of the force are given It is easy to prove that a change in any of these characteristics cause a change in the action of the force. By performing experiments, we can show that if the magnitude of the force and the point of application remained the same, the action of the force still changes because of the change in the direction of the force Finally, it is possible to show that the action of the force changes when its magnitude changes if the direction and the point of application of the force remains the same. Thus any force is determined if we have the magnitude, the point of application and the direction of the force. For many purposes in physics a force is represented graphically by a line with a direction, The length of a line on an

accepted scale represents the magnitude of the force One end of this line has an arrow which indicates the direction of the action of the force and the other end of this line shows the point of application.

IV. Retention.

Solving problems on graphical representation of forces.

V. Home work.

LIST OF DEMONSTRATION OF THE TOPIC "*COMPOSITION OF FORCES, EQUILIBRIUM OF FORCES*"

1. Manifestation of the force due to the weight, as pressure exerted on the support or as stretching the thread from which it is suspended
2. Deformation of an elastic ruler under the impact of a weight.
3. Motion of a block along the surface of a table caused by a tractive force.
4. Other conditions being equal, the action of the force depends on the point of application of the force.
5. All other conditions being equal, the action of the force depends on its direction.
6. Other conditions being equal, the action of the force depends on its magnitude
7. Composition of two forces acting along the same straight line in one direction (with the help of a spring)
8. Composition of two forces acting along the same straight line in one direction (with the help of demonstration dynamometers)
9. Composition of two opposite forces acting along the same straight line.
10. The centre of gravity of homogeneous bodies of regular shape is determined by the centre of symmetry of the bodies
11. Determination of the centre of gravity of bodies of irregular shape.
12. Types of equilibrium of bodies which have the axis of rotation :
    (*a*) Stable equilibrium
    (*b*) Unstable equilibrium
    (*c*) Neutral equilibrium
13. Equilibrium of a ball resting on different surfaces.
14. The principle of a toy based on stable equilibrium
15. Conditions of equilibrium of bodies resting on a support.
16. Dependence of stability on the height of the body.
17. Dependence of stability on the surface area of the support.

CHAPTER III

Work and Energy Machines

I. *The Aim of the Topic*

This topic is of primary importance both scientifically and technologically. Such concepts as work and energy are among the fundamental concepts of physics These concepts are basic for understanding one of the most important laws of nature—the law of conservation and transformation of energy. The polytechnical importance of this topic lies in the fact that such concepts as mechanical work, power and the efficiency of machines are essential for characterising the working of the simplest machines as well as complex machines. Finally this topic is important not only because the concepts work, energy, power, etc. which are introduced here, are the most essential concepts in mechanics but because they are used in dealing with all the other topics of the course of physics. Hence it follows that the successful study of these basic concepts of physics will help the students to understand more profoundly the other topics of the course of physics.

II. *Contents of the chapter*

This chapter covers, under the syllabus for class VII, the following points :

1. Mechanical work. Units of work : kilogram wt, metre and joule.
2. Power. Units of power : kilogram wt metre per second, the horse power.
3. Lever. Moment of force : conditions of equilibrium of lever.
4. Pulleys.
5. The law of the equal amount of work irrespective of the machine used (the lever, the inclined plane etc) proved experimentally.
6. Coefficient of efficiency of simple machines.
7. Rotary motion. Rotations per unit time (on the examples of belt and gear transmission).
8. Potential Energy of a raised body and a compressed spring

9 Concept of kinetic energy of a moving body. The energy of rivers and the wind

10 Transformation of energy.

III. *Analysis of the most important concepts of the chapter*

1 *Concept of work :*

The correct scientific concept of work can be evolved only on the basis of the law of conservation and transformation of energy This law serves as a basis for the inception of the idea of work as a process of transformation of energy when it is transmitted from one body to another Work is one of the forms of energy transmission from one body to another. Generally speaking, there are only two forms of transmission of energy from one body to another, *e g*, work to heat and vice versa. Transmission of energy in the form of work has an important characteristics When energy is transmitted in the form of work there always takes place transformation of the energy of one type into the energy of another type. To prove the validity of this statement let us consider a number of concrete cases.

(*a*) Lifting the body uniformly to some height:

(*b*) Motion of a body on a horizontal surface:

In this case the force acting on the given body transfers energy to the displaced body in the form of P.E and the kinetic energy of the displaced body At the same time the K E of the moving body is partially transformed into heat energy due to friction.

In this case the force lifting the body to some height performs work, *i. e.*, it transfers energy from one body to another As soon as the force is removed, the speed of the body moving upwards decreases Here, in doing so, the K E of the moving body is transformed into P. E. (neglecting the force of resistance due to air).

(*c*) Elastic collision of two balls .

In this case if the moving body collides with a stationary ball, the first ball performs work in respect to the second, *i e*, there takes place transmission of energy from one ball to the other. At the same time transmission of the different types of energy is also observed. Indeed deformed in this process first, the kinetic energy of the body is transformed into potential energy of the deformed body and the potential energy is again transformed into kinetic energy.

(*d*) Inelastic collision:

In this case work is performed as well, *i. e.*, the energy of one body is transferred to the other and at the same time we observed transformation of the energy of one type into another. Here, as in point (c) we observed transformation of the kinetic energy into the potential energy of the deformed ball and partially reverse transformation into kinetic energy as well as internal energy detected by the increase in the temperature of the balls. Hence, work is a form of energy, transferred from one body to another and is always accompanied by transformation of the type of this energy. From it follows that the amount of work is a measure of the amount of energy transferred from one body to another or transformed from one type into another It is easy to prove that work is measured by the product of force and the displacement of the body caused by this force in the same direction. In other words if we denote the amount of work by W, the acting force by F and the displacement by S, we can write $W=F \times S$. In this case the direction of the action of the force F and the direction of the displacement S coincide. More generally the amount of work can be calculated by the formula, $W=F.\ S.\ \cos\theta$.

Where θ is the angle between the direction of the acting force and the direction of the displacement. To prove this formula let us analyse a particular example. Let us consider due to the motion of a carriage on a horizontal surface with speed V provided there is no resistance friction. In this case, the work done by the force will be spent completely increasing the kinetic energy of the carriage. Consequently we can write down that $W = \frac{mV_2^2}{2} - \frac{mV_1^2}{2}$ (I) where m is the mass of the carriage, V_1 the initial speed of the carriage and V_2 the final speed of the carriage. Under the formulae of the kinematics of uniformly accelerated motion, we can write down $V_2^2 - V_1^2=2a.S$ or dividing this equation by 2, we shall get $\frac{V_2^2}{2} - \frac{V_1^2}{2} = a.\ S.$

Using this equation in formula I we get,

$$W = \frac{mV_2^2}{2} - \frac{mV_1^2}{2} = m.a.S$$

But under Newton's second law $F=m.\ a.$

Substituting the value of ma from this formula we shall finally get

$$W = \frac{mV_1^2}{2} - \frac{mV_1^2}{2} = F.S.$$

$$W = F.S.$$

Which was to be proved This formula of work is valid for forces of any origin and for motions of any trajectory. If we analyse the most general formula of work

$$W = F.\ S.\ \text{Cos}\ \theta$$

It can be easily seen that mechanical work is performed only if a body is acted by the force $F \neq 0$, and the force causes displacement of this body, *i. e.*, $S \neq 0$. There may be cases when a force F is not equal to zero, acts upon a body but mechanical work is not performed if the force is directed at right angles to the displacement of the body, *i e*, $\cos 90^\circ = 0$ and consequently $S \cos 90^\circ = 0$ and work $W = 0$. This formula shows that work can be negative if the force is directed at an obtuse angle to the motion and it does not help but prevents motion In this case, it is said that a force performs negative work For instance, the force of friction always slows down motion, *i e.*, it performs negative work. Since work is nothing but a change of energy, work and energy (both kinetic and potential) are measured in the same units The unit of work can be easily obtained on the basis of the formula $W = Fxs$. In the CGS system the unit of work and energy is one erg. One erg is the work performed by the force of one dyne acting through a distance of 1 cm.

$$1\ \text{erg} = 1\ \text{dyne} \times 1\ \text{cm}.$$

This unit of work is very small. In technology a larger unit of work is used which is called kilogram wt metre. This is the work performed by the force of one kilogram weight acting through the distance of one metre.

1 kg wt metre $=$ 1 kg wt $\times$ 1 metre

1 kg wt m $=$ 98,100,000 ergs

Another unit of work and energy is joule One joule is the work done by a force of one newton through a distance of one metre.

$$1J = 1Nx1\ m.$$

1 kg wt m $=$ 9.8 J

It is easy to calculate and show that one kg wt metre is equal to 9.8 joules.

2. *The concept of Energy*

The concept of energy is one of the most complex concepts in physics. This concept was eventually formulated in the middle of the 19th century, *i e.*, considerably later, than the concept of work. The analysis of this concept is possible only by proceeding from the facts of the transformation of one form of motion of matter into other forms. In physics, motion is understood as a change in the state of a system leading to a corresponding change in the definite group of parameters determining the state of the system relating to every specific form of motion Thus the mechanical forms of motion are characterised by changing coordinates and speed, heat by changing temperature, volumes and pressures, electro-magnetic

form of motion is characterised by changing electric and magnetic properties of the field etc. One of the most important achievements of the science of the 19th century was the discovery that all the physical forms of motion are mutually transformable. The fact that any kind of motion can be transformed into another is proved by the fact that different forms of motion can cause similar changes in the state of a system. Thus the temperature of a metal rod can be increased by some degrees by means of different outside actions by performing work in respect to it : (*i*) by mechanical action, (*ii*) by heating it in a flame, *i. e.*, by heating treatment, (*iii*) by applying electric current etc. This enables one to compare the different forms of motion and to establish equivalent correlations among them. Among various outside actions causing change in the state of a system there always can be mechanical actions Consequently, measuring makes it possible to establish the amount of mechanical work equivalent to a given action Thus it is in this sense that we should understand the equivalence of heat and work Consequently, the possibility of a quantitative comparison between outside actions leads to the definition of the concept of energy Energy may be defined as a quantity representing the state of a system It is changed when the system is transformed from one state into another and is determined by outside actions represented in the amount of mechanical work equivalent to them Let us clarify this statement on the example of purely mechanical process In mechanics we consider the following three forms of energy

1. The kinetic energy of a body. The energy of a moving body, $E_k = \frac{mv^2}{2}$.
2. Potential energy which may be in two forms:
   (*a*) The energy of interaction of two bodies (the potential energy of a body at rest above the earth)
   (*b*) The energy of interaction of the particles of the same body (the potential energy of the pressed spring).
3. The entire mechanical energy of a body consisting of the sum of the kinetic and potential energy of a body or the system of bodies.

$$\underset{\text{(Total)}}{E} = E_k + E_p$$

Hence if we represent the mechanical energy of a system in one state by E_1 and the mechanical energy in another state by E_2, then for entirely mechanical processes, we get the following equation

$$E_2 - E_1 = W,$$

where W is the amount of the mechanical work performed by the outside forces, under the impact of which the system changed from one energy state into another. If we have an isolated system which does not experience any outside action then

$$E_2 = E_1,$$

and consequently, $W=0$. This means that the energy of an isolated system remains constant whatever mechanical processes occur within it. This statement represents the law of conservation of energy applied to entirely mechanical processes. Consequently the law of conservation of energy applied to mechanical phenomena may be formulated in the following way. The full mechanical energy of isolated system of bodies is a constant quantity.

$$E(\text{Total})=\text{Constant}$$

$$E_k+E_p=\text{Constant.}$$

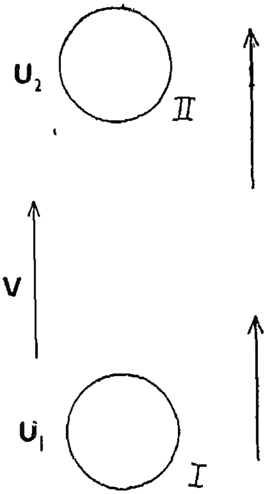


Fig. 28

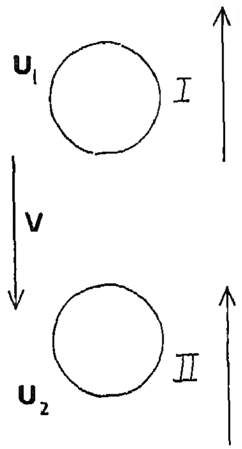


Fig. 29

From this equation it follows that when the potential energy of a system increases, the kinetic energy decreases and the total mechanical energy of the system remains constant Let us analyse a number of concrete examples illustrating equation I. Let us assume that a body having a weight P possesses the potential energy E_p. If this body is raised to a height *h*, its potential energy will become E_p. The difference in the amount of energy of the body in the former and the latter states will be equal to the amount of work done against the force of gravity performed by the outside forces, *i. e.*, $E_{p2}-E_{p1}=W$ (Figure No. 28) If the mass of a body is m, the amount of work in this case will be $W=P.\ h.=mg.\ h$ and vice-versa. Under the impact of the force of gravity the body is moved from one place (I) to another (II) (Fig. No. 29) its kinetic energy changes. This change in the kinetic energy equals the work W, but under the law of conservation of energy, the increase of the kinetic energy takes place at the expense of the potential energy which decreases. Hence, the work performed by the force of gravity is equal to the decrease of the potential energy, e.g.

$$W=E_{p1}-E_{p2}$$

Let us analyse a case of the change of the potential and kinetic energy of a body in free fall (Figure No. 30). Let us assume that a body with the mass m is at the height h While the body is at rest its kinetic energy $E_k=0$, whereas its potenial energy is $E_{p1}=mgh$.

The full mechanical energy of a body represented by the sum of both the types of energy-E (Total)$=E_{k1}+E_{p1}=mgh$ What will be the change in the kinetic and potential energy of the body in t seconds after the start of the free fall of this body When the body is falling the height decreases. Consequently, the potential energy also decreases. In t seconds the height will decrease by the quantity $\frac{gt^2}{2}$. Hence, the decrease in the potential energy during the given time will be represented by the quantity:

$$EP_1=mg\times\frac{gt^2}{2}=\frac{mg^2t^2}{2}\text{(I)}$$

Hence the potential energy after the period of time t will be equal to the difference between the initial amount of it and the decreases of the potential energy, during this period of time·

$$E_{p2}=mgh-\frac{mg^2t^2}{2}$$

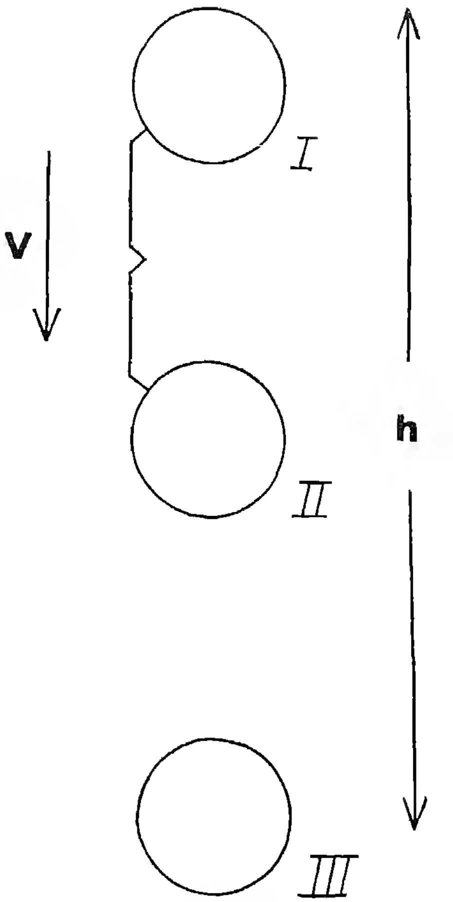


Fig. 30.

On the other hand in t seconds the speed of the body has increased by $v=gt$. Consequently, its kinetic energy also increase. This increase will be represented by

$$E_k=\frac{mv^2}{2}=\frac{mg^2t^2}{2}\text{ (II).}$$

Comparing the equations I & II, it is easy to see that the decrease in the potential energy of a freely falling body during a period of time is equal to the increase in the kinetic energy during the same period of time. Adding the amounts of the kinetic and potential energy in position II, we shall obtain $E=E_{p2}+E_{k2}$

$$E_{II}\text{ (Total)}=mgh-\frac{mg^2t^2}{2}+\frac{mg^2t^2}{2}=mgh$$

We see that the total energy in position II remained the same. Finally at the moment when the body touches the earth in position III, the potential energy transforms entirely into kinetic energy.

$$E_{p3} = 0 \quad E_{k3} = \frac{mv^2}{2}$$

Since $V^2 = 2\,gh$, so $E_k = mgh$ E_{III} (total) $= E_{p3} + E_{k3} = mgh$
Thus the total mechanical energy of a body is equal to mgh during the entire period of the fall from a height *h*, *i. e*, it remains constant

IV. *Methods resorted to in the presentation of the individual points of the topic*

We have already mentioned one of the most important concepts of this topic, the concept of mechanical work The formation of the concept of work takes place in two stages First the concept of work is introduced before the concept of energy is studied and later after the law of conservation and transformation of energy has been studied The necessity to introduce the concept of work before the law of conservation of energy is explained by the importance of this concept used in analysing simple machines First the teacher should stop at the difference between the meaning of the term work as used in everyday life and in mechanics For instance in daily life we say that a composer composes music, a pupil solves a problem, an accountant makes a bill etc. There are examples of mental works, For instance, a man simply holds a weight in his hand without moving it on, he holds it on his back or head Consequently, such motions as mental work and muscular work done by a man and an animal when they are motionless, differ from the concept of mechanical work studied in physics. In mechanics work is performed only if a force acts on a body and causes displacement of this body. Experiments and a correct explanation of them will largely help students to clarify this concept to them The first set of experiments should illustrate that if a force is acting on a body but it fails to cause any displacement, no mechanical work is performed. For instance, if we put a wooden block on a table and apply a force on its surface vertically downwards (using a dynamometer), no mechanical work is performed. Another set of experiments should illustrate that if a body is moving by inertia, (no force acting on it), no mechanical work is performed in this case either. For this purpose, the teacher may use an inclined plane with a flat piece of glass at its base. When we roll a ball down the plane it experiences the impact of the force of gravity whereas, when the ball moves on the horizontal part, viz. on the glass, the moving force is not acting on it, *i. e.*, the ball is moving by inertia. Consequently in this case we observe only a displacement of a body but there is no force acting upon it True, in this experiment one should remember that the ball is experiencing the impact of the force of friction. This force performs negative work. Finally the teacher should perform a demonstration, showing the case, when

there is an acting force and this force causes displacement of the body For this purpose we can load a wooden block with weights and connect it with thread to a demonstration dynamometer With an effort of the hand applied to the dynamometer, we move it together with the block. In this case mechanical work is performed. The results of all these three demonstrations can be written down in the following way· representing mechanical work by W, the acting force by F and the displacement of the body by S we obtain .

If $S=O$ and $F \neq O$ then $W=O$

or $F=O$ and $S \neq O$ then $W=O$

or $F \neq O$ and $S \neq O$ then $W \neq O$

To substantiate logically the concept of work in mechanics, it is necessary to analyse a number of examples from technology Thus the motion of a drill, a chisel and other functioning parts of machines cannot occur by inertia because they experience the resistance of the parts which are being worked at and various forms of friction. Thus resistance decreases the speed of the moving parts For a chisel, drill or other functioning parts of machine tools to be in motion for a long time in defiance of the resistance, a force must be applied to them (this force must at least be equal to the force of resistance) These examples show that mechanical work is performed when displacement of bodies takes place owing to the action of a force or forces. After analysing the technological examples, it is necessary to pass over to demonstrations aimed at illustrating the performances of mechanical work against the force of friction and the force of gravity Using these examples as a basis and implementing the inductive method, the teacher should show that the magnitude of the work performed increases with the increase either in the magnitude of the force acting on a body, or on the magnitude of the displacement. In other words, it is necessary to substantiate the validity of the formula used for calculating the magnitude of mechanical work.

$W=P.\,h$—the formula used for calculating mechanical work performed against the force of gravity when the body is raised uniformly to a height h

And the formula for calculating the amount of mechanical work done against the forces of friction for a particular case when the direction of the action of the force coincides with the direction of the displacement of the body under the impact of this force is, given as

$W=F.\,S,$

Naturally after having introduced the formulae for calculating the magnitude of mechanical work, it is necessary to introduce the unit of measurement of this physical quantity which is new to the students. At this stage, however, we may introduce only one unit—the unit of kilogram weight metre. This unit is introduced on the basis of the given formulae:

$W=P.\,H.$

or $W=F.\,S.$

If in the right-hand portions of these equations we shall have one kilogram weight for the unit of force and metre for the unit of distance, we shall get the unit of mechanical work kilogram wt metre. After that the teacher should give the definition of this unit of work in words For instance the work of one kg wt m is performed when a weight of one kilogram is raised uniformly a height of one metre or we may say that the work of one kg wt m is performed by the tractive force of one kilogram wt., when a body is displaced through one metre. In addition to this unit of work one kilogram wt metre, it is necessary to introduce another important unit of work—one Joule. However, in this course of physics we only introduce it without elaborating on the nature of this unit. We also give the correlation between these two units of work, *e g.*, 1 kg wt m=9.8 joules. To facilitate the learning of these formulae by pupils, it is necessary in the course of discussion of the whole topic and during the periods specially allocated for this purpose to solve many qualitative and quantitative problems Later, we suggest a number of problems on the entire topic.

II. *Power*

After the discussion of the concept of mechanical work, it is necessary to proceed to the analysis of the concept of power This concept following the concept of mechanical work is understood easily by pupils provided the pupils have assimilated the concept of work very well We draw pupil's attention to the fact that in technology, in plants, factories, in agriculture, etc , one often has to compare similar work performed by machines and human beings. In determining the capability of particular machines or particular workers, it is necessary to understand that the knowledge of the magnitude of mechanical work alone is not sufficient. Indeed if one wants to compare the capabilities of two machines or the work of two workers, the amount of the work performed will not help to answer this question. Let us assume that one machine has performed work W_1 equal to 100 kg wt m and the other performs work W_2 equal to 200 kg wt m. Can we say that the second machine is more capable? No, we can't . Because we do not know the time which was spent on this work by the machines which we compared. On the other hand the teacher should give pupils some other examples For example, let us assume that two machines performed an equal amount of work 250 kg wt m each Can we say that both these machines had the same capability. The teacher should pose the following question What else must we know in order to answer the question: "Which of these machines has a greater capability? Consequently the knowledge of the amount of mechanical work alone as well as the knowledge of the time of work alone does not enable one to answer the question Thus we help the students to realize that to compare the capability of machines and the work of a man, one must know the amount of work which is performed by them as well as the period of time during which this work was performed Consequently

the capability of different machines as well as the work of a man can be compared by the amount of work performed in unit time. After these reasonings, it is necessary to pass over to demonstrations. In these demonstrations the teacher should show the performance of mechanical work together with measuring the amount of the work and the time spent on it After that the teacher gives the formula for calculating the power·

$$N=\frac{W}{t}$$

Following this the teachers should introduce the unit of power and give the following units

$$1\ \frac{\text{Kg wt m}}{\text{sec.}}=\frac{\text{kg wt m}}{\text{sec}}$$

$$1\ \text{H.P}=\frac{75\ \text{kg wt m}}{\text{sec.}}$$

$1\ \text{watt}=\frac{1\text{J}}{1\ \text{sec.}}$ · This general formula

$N=\frac{W}{t}$ for calculating the magnitude of power does not depend upon the type of motion (both in uniform and non-uniform motion) of a body. It is also necessary to give the formula which is applicable for calculating work in uniform motion only In fact it may be easily derived by the pupils themselves. From the basic formula it follows that power $N=\frac{W}{t}$. As W by $F\times S$ the mechanical work $W=F\text{x}s$ so by substituting the work in the formula of power we obtain $N=\frac{F\ S}{t}$. We know from mathematics that to divide the product of two factors by a number is sufficient to divide one of the factors. Hence we may write down as $N=\frac{F\ S}{t}$ but the ratio of $\frac{S}{t}$ is equal to V, the speed of uniform motion. Substituting the speed of uniform motion, V for $\frac{S}{t}$ we obtain

$$N=F\times V$$

Whereas F is the tractive force and
V is the speed of uniform motion.

Since in most cases we observe non-uniform motion, it is necessary to calculate the power developed by various machines having uniform motion. The power

developed in non-uniform motion is represented by the average power in a given period of time For instance, if under the impact of a force F acting for a period of time t, changes the speed from v_1 to v_2 then the average speed can be calculated by the following formula:

$$V_{av} = \frac{V_1 + V_2}{2}$$

Hence the average power can be calculated by the following formula:

$$N_{av} = F \times V_{av}$$

Teachers should solve a great number of quantitative problems to assimilate these formulae properly.

III. *Simple Machines*

This sub-topic is important because in technology simple machines are used very widely. From everyday life pupils know or, rather, see the various cases of implication of simple machines, for example, levers, windlass, fixed and movable pulleys and inclined planes The significance of this topic lies in the fact that basically the more complex up-to-date equipment and machinery consists of the various combinations of these simple machines. It should be explained to pupils that the study of this topic is very important because these machines are intended for serving man and helping him in his exhausting manual labour The history of the invention of these simple machine goes back to the ancient times. As early as the third century B. C these devices were used for lifting and moving heavy things, set in motion various weapons. All these devices served for performing of bodies against considerable forces (for instance when weights had to be lifted—against the force of gravity). To achieve this the forces developed by the devices must, at least at the start, exceed the forces resisting the motion But if the motions caused by the devices are slow we can see that the role played by these devices is reduced to balancing the exceeding forces resisting the motion. All such devices are called simple machines. Thus when we discuss the action of simple machines we only have to find out the conditions under which a simple machine is in equilibrium One of the simplest type of such machines is the lever. The lever is a solid body having the axis of rotation or the point of support around which the body may rotate under the impact of forces. First the teacher should show the students the demonstration of rectilinear lever and clarify to them the principles on which the lever works. He should also introduce the concepts of the point of application of forces, the line of action and the arms of forces. Special attention should be paid to the correct formulation of the concept of the arm as the shortest distance between the point of support to the line of action of force, since pupils often erroneously regard as the arm the distance between the point of support to the point of application of the force irrespective of the direction of the

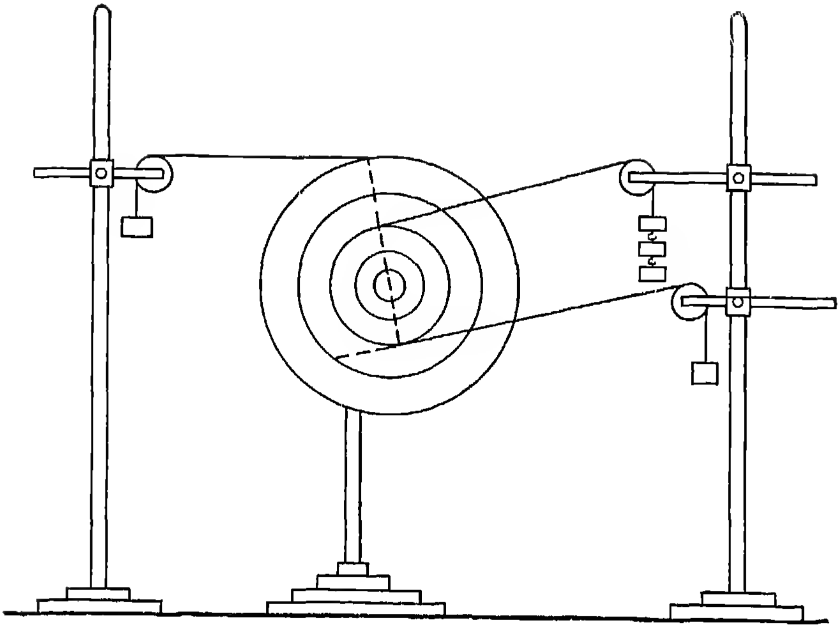


Fig. 31.

latter (figuıe No. 31). Then the teacher should show that the use of a lever allows a gaın in force After that on the basıs of a demonstration with the eus of a demonstratıon lever (usıng alternative forces and arms), the teacher proves that lever ıs in equılibrium if the aıms aıe ınversely proportıonal to the forces.

$$\frac{l_1}{l_2}=\frac{F_2}{F_1}$$

Applyıng the law of propoıtıon, we obtain:

$$F_1 \cdot l_1=F_2\ l_2$$

Here the concept of the moment of forces is introduced and another formulation ıs gıven of the conditions of equilibrium of the leveı. The lever ıs ın equılibrıum ıf the moments of the foıce rotatıng the lever in the clockwıse directıon equals the moment of force rotatıng the lever ın the antı-clockwıse dıiection. Experıence shows that teacheıs sometımes do not pay adequate attentıon to thıs ımportant propeıty of the lever oı they dıscuss ıt wıth theır pupıls only foımally. It is necessary, therefoıe, to substantıate the condıtions of the equılıbrıum of the lever by a number of demonstratıons and explaın ın detaıl what forces rotate the lever ın the clockwise dırectıon and what forces ıotate the lever ın the antı-clockwise

direction The next stage in the presentation of the material is proving that the application of a lever does not bring about any gain in work True, this can be easily shown by demonstration No 14. In this demonstration a rectilinear lever is suspended from a thread, the other end of which is fastened to a nail fixed to the classboard. A weight of 200 grams is attached to one of the arms of the levers which is 20 cm. long whereas a weight of 100 grams is attached to the longer arm of the lever which is 40 cm long. After the levers have been set in equilibrium, a horizontal line should be drawn with a chalk on the blackboard indicating the position of the lever and the points of application of the forces. Then changing the position of the lever (from horizontal line) by hand, the teacher draws another line indicating the new position of the lever. Then adjusting a ruler to the classboard, it is easy to find the magnitude of the vertical displacement of the points of application of the forces. One easily observes that these lines represent the distance covered under the impact of the forces. A distance of 10 cm is covered under the impact of the force 200 grams whereas the distance of 20 cm is covered under the impact of the force of 100 grams. This experiment shows that the work of both forces acting on the lever is equal to

$W_1 = F_1 \times h_1 = 200 \text{ gwt} \times 10 \text{ cm} = 2000 \text{ gwt cm.}$

$W_2 = F_2 \times h_2 = 100 \text{ gwt} \times 20 \text{ cm} = 2000 \text{ gwt cm.}$

$\therefore W_1 = W_2$

The syllabus includes special laboratory work to make easy the assimilation by students of the condition of equilibrium of the lever. In this work pupils do experiment independently with rectilinear levers and once more see the validity of the conditions of equilibrium of the lever. This sub-topic should be concluded by discussing the various technological applications of the lever to facilitate pupils comprehension about the principles of the working of the lever The teacher should acquaint them with different types of levers. It is not necessary to divide levers into classes, it is sufficient if the teacher points out that in some levers the forces are applied to the opposite sides from the point of support, whereas in other levers the forces are applied on one and the same side from the point of support Pupils should become acquainted with the following tools and devices based on the principle of the lever : the spanner, the scissors, the scissors for cutting metals, pliers, the pulley, the water pump with handle etc. At the same time in all the lessons acquainting pupils with the technological applications of the lever, it is necessary to solve calculation and qualitative problems without which this sub-topic cannot be properly assimilated. The knowledge of the lever should serve for the understanding of the basic characteristic of mechanics according to which no gain in work can be achieved by using any simple machine. By using simple machines, we can gain in force but at the same time we loose to the same extent in distance and consequently we fail to gain in work These important characteristics of any simple machine should be discussed when we deal with pulleys, inclined planes and windlasses. After the examination of the lever, the teachers should

pass to the discussion of the fixed pulley, then to the movable pulley, the windlass and the inclined plane. The discussion of all these simple machines should be carried out on the same line as in the discussion of the lever as follows :

1. Demonstration of the machine and its construction
2. The purpose for which this machine serves in everyday life and technology.
3. Principal characteristics of the machine as shewn by demonstration.
4. Proving the impossibility to gain in work by using this machine
5. Technological application of the machine.
6. Solution of problems.
7. Laboratory work.

It should be borne in mind that the discussion of all the types of simple machines and their properties takes place on the assumption that all these machines are ideal machines, *i e* , the forces of friction are ignored

Energy

Clarification of the concept of energy in the physics course for class VII

We recommend to begin the presentation of this sub-topic with the revision of the conditions under which mechanical work is performed. Then the teachers should proceed to the discussion of cases when mechanical work is performed by objects in motion. These may be :

1. A shell can make a hole in an obstacle which it hits; the moving masses of air (the wind) rotate the vanes of wind mills , a stone having some initial speed achieves some height performing work against the force of gravity, etc. These and similar examples which can be cited by pupils themselves may serve as a basis for the conclusion that ;

In all these cases some mechanical work is performed because there are two factors present the action of forces and the displacement of bodies under the impact of these forces

Every moving body is capable of performing mechanical work. After that the teacher should support this conclusion with simple demonstrations. One such demonstration may be the displacement of a wooden block by a ball rolling down along an inclined plane. This demonstration convinces pupils that a moving body which has some speed is capable of performing some mechanical work. In terms of physics, it is said that if a body is capable of performing work it possesses energy. Hence it follows that every moving body possess energy. The energy which is possessed by any moving body is called kinetic energy. The word *kinetic* comes from the Greek word 'Kinema' which means motion. On introducing the concept of kinetic energy the teacher can, on the basis of the same simple experiment, find out on what factors the kinetic energy of body depends. Considering the

amount of work performed by the ball rolling down along the inclined plane, to displace the wooden block it is possible to show that the amount of the mechanical work which the ball can perform depends on the speed of the ball For this purpose two experiments are performed in which the ball rolls down from different heights. This experiment helps pupils to draw the conclusion that the amount of the kinetic energy of a body depends on the speed of the body namely, the greater the speed the greater the kinetic energy of the body because in this case the body performs more mechanical work The second series of experiments is aimed at finding out that at the same speed of motion, the amount of the kinetic energy of a body depends on the mass of the moving body For this purpose, by using the same set up, we show that if we roll down from the same height two balls having different masses, the balls perform different amounts of work namely, the more mass the body has, the greater is the amount of the kinetic energy of the body Now, on the basis of the results of both the experiments we can draw the general conclusion that the amount of the kinetic energy of a body is proportional to the speed of the motion of the body and to the amount of the mass of the body Then the teacher may tell his pupils that the physics theory and precise experiment shows that the amount of the kinetic energy of a body can be calculated by the formula,

$$E_k = \frac{mv^2}{2}$$ where m is the mass of the body and

v is the speed of the body.

NOTE : The teacher should bear in mind that the syllabus does not contain this formula. Therefore, only to the pupils having enough background, this formula *should* be given.

From the definition of the concept of energy it follows that it is to be measured in the same units as mechanical work, i.e., the kinetic energy of a body can be measured in kilogram wt metres or joules. To facilitate pupils' assimilation of this important concept the teacher should give them quite a number of qualitative and experimental problems to be solved involving the kinetic energy of a body. It is essential to examine how the concept of kinetic energy is implemented in technology For instance, the teacher is advised to tell the pupils how the kinetic energy of the water stream is used when it flows out at a high speed and a high pressure in the extraction of coal as well as in constructing tunnels, subways etc. After doing this, the teacher should pass over to the explanation of the concept of another type of mechanical energy—that of *potential energy*. The teacher should begin with a revision of the definition of energy (already familiar to pupils) as the capability of a body to perform mechanical work. Hence, the natural question arises : Is it that only *moving* bodies possess energy? The pupils should be shown that raising a body to some height is associated with performing mechanical work,

In this demonstration, a weight raised to some height with the help of a fixed pulley, falls down on a wedge placed in a box with sand When the weight falls on the wedge the latter goes into the sand performing work against the forces of resistance Thus, on the basis of this demonstration we can draw the following conclusion

When a body is raised to some height, it possesses energy because this body is capable of performing certain mechanical work This type of energy is called potential energy Consequently, every body raised to some height possesses a certain amount of potential energy The question may be put to pupils On what does the amount of potential energy of a body depend? To anwer this question the teacher should perform the following two series of experiments.

1. To make clear whether the amount of potential energy of a body depends on the height to which the body is raised For this purpose the previous set up can be used to show that the greater the height to which the body was raised, the greater is the mechanical work performed by the body and consequently, the greater is the amount of the potential energy of the body.

2. Then the following question is asked Does the amount of the potential energy of the body depend on the mass of the body if the height remains the same? To answer this question, we use the previous arrangement of two bodies having different masses and falling from the same height. The pupils may easily draw the conclusion that the bigger the mass of the body, greater is the amount of the potential energy, since the amount of the work done is greater (the wooden wedge penetrates more deeply into the sand). Summing up the results of both the experiments, we may say that the amount of the potential energy of a body raised to some height is proportional to the mass of the body and the height. Then the teacher may tell the pupils that the theory of physics as well as precise experiments show that the amount of the potential energy of the body can be calculated by the formula :

$$E_p = m\,gh = P.h$$

Where P is the weight of the body and h is the height to which the body is raised.

Like kinetic energy, potential energy is measured in units of mechanical work—kg wt m and joules. Then, on the basis of the concept of potential energy, the teacher should discuss the application in technology of the potential energy of bodies, and solve with pupils quantitative and experimental problems.

The teacher then proceeds to discuss yet another type of potential energy namely, the potential energy of the compressed spring For this purpose the demonstration should be shown in which the pressed spring fixed provisionally by a thread and then released, performs mechanical work raising a body to some height, *i.e.*, work against the forces of gravity. In addition to the potential energy of the compressed spring it is advisable to demonstrate the potential energy of a gas in a cylinder compressed by a piston, and other examples.

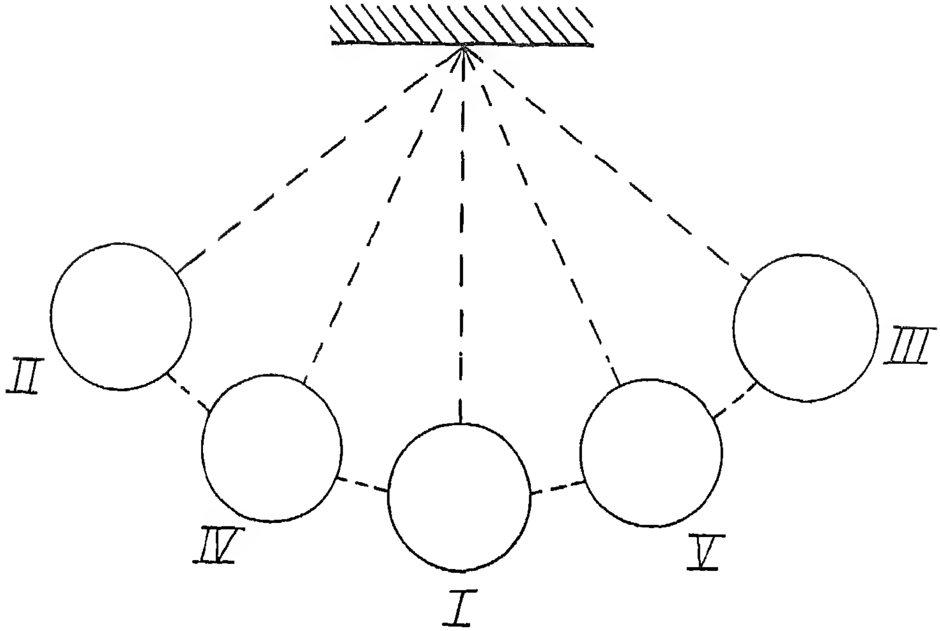


Fig. 32

On the basis of the concept of kinetic and potential energy the teacher introduces the concept if total mechanical energy, the aggregate of kinetic and potential energy.

E full = E kinetic + E potential

The concept of the total energy should be introduced on the basis of a simple demonstration of the oscillation of a thread pendulum (Fig. No. 32). If we represent the potential energy of the pendulum in equilibrium (I) equal to zero.

$$E_{P_1} = O$$

In the extreme positions II and III the potential energy of the pendulum is maximum (since the centic of gravity of the ball is raised to the height has compared to the centre of gravity in position I). If we ignore the resistance of the air and of the friction at the point of suspension of the pendulum, it will be possible to show that the law of conservation of energy is valid in mechanics.

When the pendulum oscillates, it has the maximum speed V in passing the lower position I, consequently it has the maximum kinetic energy.

$$E_{k_1} = \frac{mv^2}{2}$$

In the extreme positions (II) and (III) pendulum does not possess any speed and consequently its kinetic energies in these extreme positions are equal to zero. Hence, ignoring the resistance and friction, the kinetic energy of the pendulum in position (I) is equal to the potential energy of the pendulum in the extreme positions (II) and (III)

$$Ep_{II} = Ep_{III} = mgh$$
$$Ep_{II} = Ep_{III} = Ek_1$$

So, $$mgh = \frac{MV^2}{2}$$

In any of the intermediate positions IV or V the oscillating pendulum possesses kinetic energy In these positions the speed of the pendulum is different from zero and the pendulum also possesses potential energy because its centre of gravity is higher than the centre of gravity in position I. However, the total of the kinetic and the potential energy of the pendulum is equal to the potential energy in position II and III or to the kinetic energy in position I

Thus this analysis helps pupils to see the validity of the law of transformation and conservation of energy in mechanical processes. The problem is then that pupils should make clear that energy can neither be created nor it can be destroyed; it is only transformed from one type into another.

In addition to the demonstration of the thread pendulum, it is desirable to show how energy is transformed from one type into another on the following examples: the oscillation of a vertical cord pendulum, oscillation of a horizontal spring pendulum and, finally, oscillation of Maxwell's pendulum which usually impresses pupils very much It should be borne in mind that after studying the chapter on heat for introducing the concept of internal energy of the body, the teacher will have an opportunity to elaborate on this fundamental law associated with the mechanical and thermal phenomena. On the clarification of this law the teacher may draw pupil's attention to the fact that before the discovery of this law people tried for many years to devise many types of perpetual motion machines.

However, none of these projects could be realized. Therefore, it is advisable to show pupils the sketches of some projects of perpetual motion machines and to analyse with pupils for what reasons such a machine cannot be created. A detailed analysis of this question may serve as an interesting topic in the out of class work with pupils.

PROBLEMS ON THE TOPIC

I. *Mechanical Work*

1 Give examples of mechanical work in overcoming the force of gravity.

2 Give an example of mechanical work done by a body when it overcomes the resistance due to friction.

3. Does the force of gravity, acting on a weight kept on the table, perform any work?

4. How much work is done when a load of 40 kg wt is raised to a height of 120 centimetres?

5. Calculate the amount of the work performed when a load of 2300 kg wt is raised with the help of a crane to a height of 4 metres.

6. The cutter of the planing machine performs 300 kg wt metres of work when it covers a distance of 200 cm.

7. What are the essential conditions for work to be performed ?

8. Why is the amount of work performed by a man walking up a hill is more than the amount of work performed when he walks the same distance on a horizontal path ?

9. What amount of work is performed when a trunk weighing 150 kg wt is raised to a height of 4 metres ?

10. A box weighs 100 kg wt. To displace it uniformly on a horizontal surface, a force of 20 kg wt must be applied. What amount of work is to be performed to pull it through a distance of 10 metres or raise it to a height of 10 metres?

11. A horse is pulling a cart with an effort of 10 kg wt at a speed of 8 metres per second. What amount of work will be performed by the horse in one hour ?

12. To raise a loaded box to a height of 5 metres the 180 kg wt m of work was performed. Find the weight of the box if it is known that the weight of the load is 30 kg wt ?

13. An iron bar is raised with the help of a windlass to a height of three metres, so that the amount of work done is 11,700 kg wt m. Find the weight of the bar ?

14. What amount of work is performed by an excavator when it raises 14 cubic metres of sand to a height of 5 metres ? The density of the sand is 1.4 g per cubic centimetres (the weight of the bucket is to be ignored).

15. Water is raised by a pump to a height of 10 metres. The output capacity of the engine of the pump is 40 kg wt m per second. Find the quantity of water which the pump will raise in one hour.

II. *Power*

1. What is the power developed by a man in drawing up a bucket of water weighing 12 kg wt from a well 20 metres deep in 15 seconds ?

2. What power is developed by a worker when he puts a load of 120 kg wt on to a lorry if the load is raised to a height of 1.5 metres and the time required was 75 seconds ?

3. The engine of a water pump is capable of performing 600 kg wt m of work within 4 seconds. What is the efficiency of the machine ?

4. What is the power of a lift with the help of which a load of 300 kg wt is raised within 20 seconds to a height of 10 metres ?

5. The power of a motor car is 180 horse power. Represent this power in watts. Calculate how much horse power will be in (a) 900 kilowatts, (b) 66 kilowatts, (c) 16,5000 kilowatts.

6. Calculate the power of a pump which raises 4.5 cubic metres of water within 5 minutes to a height of 5 metres.

7. Calculate the power of a machine, which in 120 seconds raises a hammer of 200 kg wt to a height of 0.75 metres.

8. A transporter raises in 1 hour 30 cubic metres of sand to a height of 6 metres. Calculate the power of the engine to perform this work.

9. What amount of work is performed in 5 minutes by an engine of 2 horse power?

10. A motor which developed an efficiency of 30 horse power transported a load in 45 minutes. What is the amount of work done?

11. What time is required for pumping out 200 cubic metres of water from a mine 150 metres deep by an electric pump of 50 kilowatts power ?

12. What amount of work will be performed in 1 hour by an engine of 1 kilowatt ?

13. Calculate the power of a motorcar which is moving uniformly at a speed of 54 kilometres per hour if the force of friction is equal to 180 kg wt.

14. A horse is pulling a cart with a force of 60 kg wt. It takes 4 hours for the cart to cover a distance of 14.3 kilometres. Calculate the power of the horse.

15. The engine of a lathe at a speed of 720 · metres develops 6 H.P. Determine the force of resistance appearing at the instant cutting of the metal.

16. Scientists found that a whale moving under water develops a speed of 27 kilometres per hour. The power in this case will be 180 horse power. Calculate the force of the water resistance to the motion of the whale.

17. Calculate the force of resistance when a cyclist moving at a speed of 18 kilometres per hour develops a power of .1 horse power.

18. Find the average power of the engine of a mine's lift if the maximum load is 12,000 kg wt. The average speed of the lifting is 20 metres per second.

19. The power of the engine of a lift is 3.5 horse power. What load can it raise to a height of 15 metres in 2 minutes.

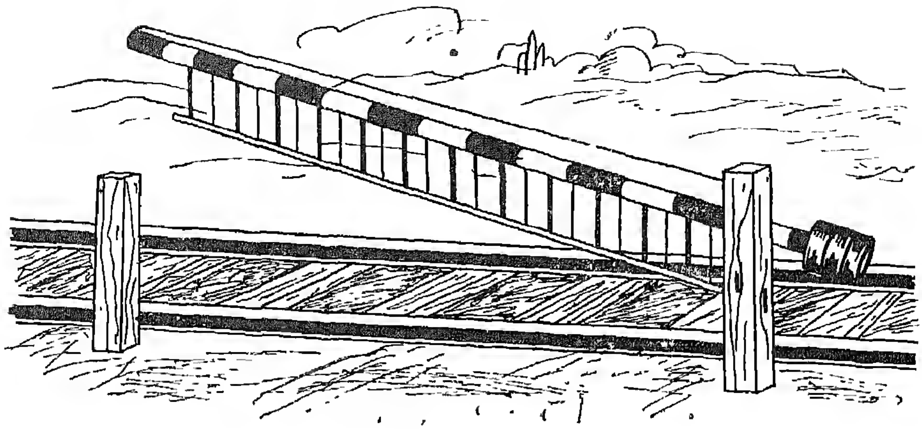


Fig. 33

III. *Levers*

1. Find the point of support and the arms of the levers (figure *No.* 33). Determine the direction of the forces which act on the levers.

2. While discussing the lever a girl draws its sketch on the classboard (figure *No.* 34). Point out the nature and place of mistake in the sketch.

3. Why is there usually counterweight attached to a crane?

4. Break a match stick into small pieces. Why is it more difficult to break further the small pieces than the bigger ones?

5. What is the easier way to cut card-board when you place it closer to the ends of the scissors or to the centre of it? Why ?

6. Why do tinsmiths use scissors with longer handles and shorter blades ?

7. Show the arms of the lever of the footbrake (figure *No.* 35).

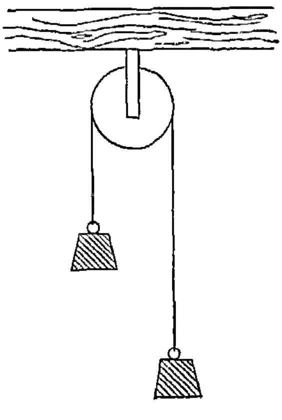


Fig. 34

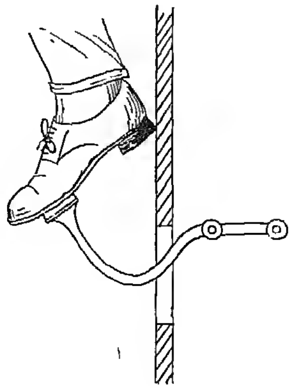


Fig. 35

8. The length of the shorter arms of a lever is 5 cm. The longer arm is 30 cm. The shorter arm is acted upon by force of 1.2 kg wt. What force must be applied to the longer arm to achieve the balancing effect?

9. One force of 400 g wt and another of 2 4 kg wt are applied to the ends of a lever. The distance from the point of support to the point of application of the smaller force is 6 cm. Find the length of the lever if the lever is in equilibrium.

10 On which of the carriages loads can be transported more easily—on a carriage with short handles or with longer handles.

IV. *Pulleys*

1. Some wells have fixed pulley. Explain why it is used if there is no gain in force.

2. What load can be raised with the help of a movable pulley weighing 2 kg wt by cafion applying to the loose end of the rope an effort of 21 kg wt, (friction being neglected)?

3. An effort of 10 kg wt is applied to raise a load with the help of a movable pulley. Find the force of friction if the weight of the pulley is 2 kg wt and the weight of the load is 16.5 kg wt.

4. A weight was raised with the help of a movable pulley to a height of 3 metres. What was the length of the loose portion of the rope which was pulled out?

5. A load was raised with a movable pulley to a height of 14 metres. What amount of work was performed by the worker in raising the load if he applied a force of 15 kg wt to the loose end of the rope ?

6. A movable pulley is used to raise a load, the effort applied to the loose end being 60 kg wt and the force of friction 2 kg wt. What is the weight of the load ?

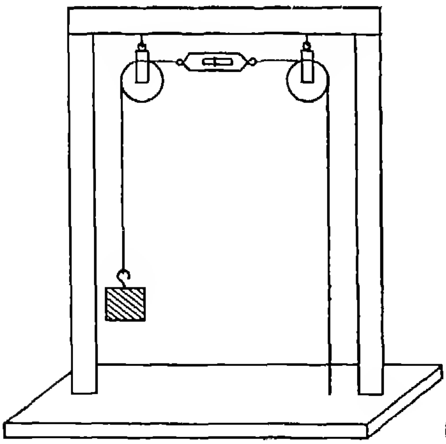


Fig. 36

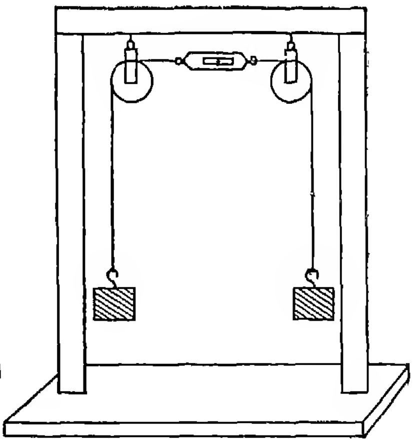


Fig. 37

7. A movable pulley is used to raise a load of 20 kg wt. The force of friction is equal to 1 kg wt. What effort should be applied to the loose end of the rope to raise the given load?

8 Discussing this topic a girl draws a chart on the blackboard (figure No. 36). What mistake did she make in the chart?

9. In figure No. 37, spring balance A shows a force of 2 kg wt. What will be the reading of the spring balance?

10. The weight of a fixed pulley is 120 g wt. The load attached to it weighs 600 g wt. What will be the reading of the spring balance if this load is raised uniformly? (friction is to be ignored)

The Windlass

1. The radius of the cylinder of the well windlass is 10 cm. The radius of the wheel is 40 cm. What force must be applied to the wheel to draw out a bucket of water weighing 16 kg wt (friction is to be ignored)?

2. A bucket of 20 kg wt is drawn from a well. The diameter of the cylinder of the windlass is 20 cm. What force should be applied to rotate the handle of the windlass, the radius of which is 40 cm.

3. The diameter of the cylinder of the windlass is 30 cm. and the radius of the wheel is 60 cm. What force should be applied to raise a bucket with sand weighing 24 kg wt (friction is to be ignored)?

4. An anchor of 120 kg wt is raised with windlass. The diameter of the shaft of the windlass is 40 cm., the length of the handle is 2 metres and the force of friction is 30 kg wt What effort should be applied to the end of the handle?

5. A windlass is used to raise a load of 40 kg wt, the effort applied being 5 kg wt; calculate the radius of the handle of the windlass if the radius of the wheel is 32 cm.

6. Find the diameter of the shaft of the windlass which is used to raise a bucket of water weighing 14 kg wt. An effort applied to the wheel is 2 8 kg wt and the radius of the wheel is 30 cm (friction to be ignored).

7. A bucket with clay weighing 64 kg wt is raised by a combination of a movable pulley and a windlass What effort should be applied to the wheel of the windlass, whose radius is 32 centimetres if the radius of the shaft of the windlass is 4 centimetres friction, the weight of the pulley and the weight of the rope are to be ignored?

The Inclined Plane

1. Which of the inclined planes (Figure No. 11) require a less effort parallel to the surface of the plane for moving the same load uniformly (friction is to be ignored)?

2. A horse is pulling uphill a cart weighing 360 kilogram weight. The length of the path is 60 metres. The height of the hill is 12 metres. Calculate the tractive force of the horse (friction to be ignored).

3. An inclined board is used to roll up a drum on a cart. The length of the board is 2 metres; the height of the cart is 8 metres and the weight of the drum is 120 kg wt. The force of friction of the drum on the board is 7 kg wt. Find the force required for the displacement of the drum.

4. Moving uphill along a path 300 metres long and 30 metres high, a motor-car weighing 1500 kg wt moves uniformly the force of friction of the wheels on the road being 50 kilogram weight. Find the tractive force of the motor-car.

5. What should be the length of a board to allow a drum of 90 kg wt to be rolled up on to a cart? The height of the cart is 1.2 metres and the applied force is 30 kg wt (friction to be ignored).

6. The work of 57.6 kg wt was done to move a load of 75 kg wt on an inclined plane. Find the height to which the load was raised (friction to be ignored).

7. A force of 40 kg wt was applied to raise a load of 60 kg wt on an inclined plane 3 metres long. Find the height of the inclined plane if the force of friction of the load on the inclined plane is 10 kg wt.

8. A load of 225 kg wt is pulled up along an inclined bridge 4 metres long and ·8 metres high. The force of friction is 22.5 kg wt. Find the efficiency of the inclined plane.

9. The reading of the dynamometer was 4 kg wt when a load was moved uniformly along an inclined plane. Find the force of friction if the length of the inclined plane is 1.8 metres, the height 30 cm and the load of 12 kg wt. Find the efficiency of the inclined plane.

10. A stone slab of 60 kg wt is pulled up to a height of one metre along an inclined board 4 metres long. Find the force of friction and the efficiency of the inclined plane if the applied force is 32 kg wt.

Energy

1. A piece of chalk and a piece of load of the same volume are placed at the same height. Which of these bodies has more potential energy?

2. What types of mechanical energy has a block of ice sliding down an ice hill?

3. What condition is required for two bodies of different masses to have the same potential energy if the bodies are raised to different heights?

4. Where is the potential energy of every cubic metre of water greater (i) at the source of the river or (ii) at its mouth?

5. Explain why it is easier to chop wood on a solid ground than on a soft ground?

6. Why does a saw become hot if it is used for a long time?

7. Into what forms of energy does the energy of a moving motor-car transform at the moment when the brakes are applied?

8. Which of the two motor-cars having the same mass possesses more kinetic energy if one of them is moving at a speed of 40 kilometres per hour and the other at a speed of 60 kilometres per hour?

9 What causes the intensive heating and burning of the artificial satellites of the earth when they enter the lower layers of the atmosphere?

10. Explain why the railway cars are provided with buffers ?

TOPICAL PLAN

No. of lesson	Date of lesson	Topic of the lesson	Method of work	Demonstration	Home work
1.		Concept of mechanical work.			
2.		Work against the force of gravity.			
3.		Work against the force of friction.			
4.		Solving problems on calculation of mechanical work.			
5.		Concept of power.			
6.		Solving problems on calculation of power.			
7.		Construction and application of the lever.			
8.		Basic characteristics of mechanics.			
9.		Solving problems on levers.			
10.		Fixed pulley—its construction and application.			
11.		Movable pulley, its construction and application.			
12.		Laboratory work—conditions of equilibrium of forces in respect of the lever and pulley.			
13.		Efficiency of simple machines.			
14.		Windlass—its construction and application.			

No. of lesson	Date of lesson	Topic of the lesson	Method of work	Demonstration	Home work
15.		Inclined plane—its characteristics and application			
16.		Laboratory work—determination of the efficiency of the inclined plane.			
17.		Rotatory motion (on the examples of belt and gear transmissions).			
18.		Concept of the kinetic energy of the body.			
19.		Concept of the potential energy of the body.			
20.		The law of conservation and transformation of energy (for mechanical processes).			
21.		Testing the students for knowledge of this topic.			

The Detailed Plan of Lessons

Lesson No. 1

Topic : Mechanical Work.

Aim : To clarify the conditions under which mechanical work is performed.

I. Introduction :

(*a*) The difference between the work as used in everyday life (mental work, physiological work) and the concept of work in physics.
(*b*) Examples illustrating performance of mechanical work.
(*c*) The significance of the topic.

II. The plan of presentation of the new material :

(*a*) Definition of mechanical work.
(*b*) Conditions under which mechanical work is performed:

(*i*) If a force acts on the body when it is not displaced, no mechanical work is performed (Demonstration).

(ii) If a body is displaced but no force acts on it, no mechanical work is performed (Demonstration).
(iii) Mechanical work is performed only if a force acts on a body and the body is displaced under the impact of this force (Demonstration).

III. Retention:

(a) Analysis of cases when mechanical work is performed or it is not performed.
(b) Review of the conditions under which mechanical work is performed.

IV. Home task.

Lesson No. 2

Topic : Work against the force of gravity.

Aim : To clarify methods of measuring mechanical work.

I. Questions to pupils:

(a) Give examples when a body is acted upon by a force but no displacement is caused.
(b) Give examples when a body is displaced but there is no acting force which causes this displacement.
(c) Give examples when mechanical work is performed.

II. The plan of presentation of the new material :

(a) Inductive drawing of the formula for calculation of mechanical work against the force of gravity (Demonstration).
(b) The units of mechanical work—kg wt m and joule and their correlation.

III. Retention of the new materials:

Solving quantitative and qualitative problems on mechanical work.

IV. Home task.

Lesson No. 3

Topic : Mechanical work done against the force of friction.

Aim : To clarify the method of calculation of the work against the force of friction.

I. Questions to pupils:
   (a) What formula is used to calculate the amount of work done against the force of gravity?
   (b) What units are used to measure work?
   (c) Which two conditions are indispensable for performing mechanical work?
   (d) Solving problems.

II. Link between the previous lesson and the present one.

III. Plan of presentation of the new material:
   (a) Cases when work is done against the force of friction.
   (b) Demonstration of mechanical work performed against the force of friction.
   (c) Calculation of work done against the force of friction.

IV. Retention :
   Solving qualitative and quantitative problems.

V. Home task.

Lesson No. 4

Topic : Mechanical work.

Aim : To teach pupils skills in solving problems involving calculation of the amount of mechanical work.

I. Retention :
   (a) The formula used for calculating work done against the force of gravity.
   (b) The formula used for calculating work done against the force of friction.
   (c) The unit of mechanical work.
   (d) Conditions under which mechanical work is performed.
   (e) The formula used for calculating the speed of uniform motion.
   (f) The formula used for calculating the average speed of non-uniform motion.
   (g) Solving problems involving calculation of mechanical work done against the weight and the force of friction.

II. Home task.

Lesson No. 5

Topic : The concept of power.

Aim : To clarify the concept of the power of a machine and the method to calculate it.

I. Questions to pupils on :

(a) The formula of the distance covered in uniform motion.
(b) The formula of the distance covered in non-uniform motion.
(c) The formula of the work done against the weight
(d) The formula of the work done against friction

II. Link between the previous lesson and the present one.

III. Plan of presentation of the new material :

(a) It is not possible to compare the capability of machines only by the amount of the work performed by these two machines.
(b) Introduction of the concept of power as the amount of work performed by the machine in one second.
(c) The method of calculating the power of a machine (Demonstration).
(d) The unit of power : kg wt m/sec.; Watt, Horse-power.

IV. Retention :

Solving problems of calculating power

V. Home task.

Lesson No. 6

Topic : Calculation of power of machines.

Aim : To teach pupils skills in calculating the power of machines.

I. Questions to pupils on :

(a) The formula to calculate the power of machines.
(b) The units of power.
(c) The formula to calculate the mechanical work done against the force of gravity.
(d) The formula to calculate the mechanical work done against the force of friction.
(e) Solving problems.

II. Plan of presentation of the new material:

(a) Deriving the formula of the power of machines developed in uniform motion :

$$N = F.\ v.$$

(b) Deriving the formula of the average power of machines developed in non-uniform motion.
(c) Solving problems.

III. Home task.

Lesson No. 7

Topic . Construction and application of the lever.

Aim : To acquaint pupils with the characteristics of the lever.

I. Questions to pupils:

(*a*) What is the characteristic of a force?
(*b*) Which two forces are called equal forces?
(*c*) What formula is used to measure mechanical work?
(*d*) Conditions essential for performance of mechanical work.

II. Presentation of the new material:

(*a*) Construction of the lever.
(*b*) Demonstration of the lever.
(*c*) Concept of the lever arm
(*d*) Concept of the moment of force.
(*e*) Conditions of equilibrium of the lever.

III. Retention :

(*a*) What is the lever?
(*b*) What is the arm of the lever?
(*c*) What is the moment of force?
(*d*) Conditions of equilibrium of the lever.
(*e*) Solving problems.

Lesson No. 8

Topic : The basic characteristic of a machine as exemplified by the performance of the lever.

Aim : To clarify to pupils that application of the lever does not give any gain in work.

I. Questions to pupils:

(*a*) What is the moment of force?
(*b*) What is the property of the lever?
(*c*) Solving qualitative and quantitative problems on the lever.

II. Presentation of the new material :

(*a*) Comparison of the amount of mechanical work performed by each of the forces acting on the lever (Demonstration).
(*b*) Finding out the basic characteristics of a machine.

III. Retention:

Solving problems on the lever.

IV. Home task.

Lesson No. 9

Topic : Application of the lever in technology.

Aim : To clarify to pupils the physical foundation of the performance of the devices and instruments using the principle of the lever.

I. Questions to pupils:

(*a*) What is the lever?
(*b*) What is the arm of force?
(*c*) What is the moment of force?
(*d*) What are the conditions of equilibrium of the lever?
(*e*) What is the basic characteristic of a machine?
(*f*) Solving problems on the lever.

II. Presentation of the new material:

(*a*) The principle of performance of the spanner.
(*b*) The principle of the performance of the scissors.
(*c*) The principle of performance of the pliers.
(*d*) The principle of performance of the pulley for carrying loads.
(*e*) The principle of performance of the lifting gate at railway-crossing.
(*f*) Application of a shelf for carrying loads.

III. Home task.

Lesson No. 10

Topic : The fixed pulley.

Aim : To clarify to pupils the construction, the properties and the application of the fixed pulley.

I. Questions to pupils:

(*a*) What are the conditions of equilibrium of the lever?
(*b*) How does the lifting gate of the railway-crossing work ?
(*c*) What formula is used to calculate mechanical work ?
(*d*) What is the difference in the construction of the office scissors and the scissors used for cutting iron ?
(*e*) Solving problems on the lever.

II. Presentation of the new material :

(*a*) Demonstration of a fixed pulley.
(*b*) Construction of a fixed pulley.
(*c*) Characteristics of the fixed pulley.
(*d*) Demonstration of the equality in the amount of the work performed when a fixed pulley is used.
(*e*) Application of the fixed pulley in technology.

III. Retention :
Solving problems on the fixed pulley.

IV. Home task.

Lesson No. 11

Topic : The movable pulley.

Aim : To clarify to pupils the construction, the properties and the application of the movable pulley.

I. Questions to pupils on :
(*a*) Construction of a fixed pulley.
(*b*) Properties of a fixed pulley.
(*c*) What are the technological applications of the fixed pulley?
(*d*) Solving problems of a fixed pulley.

II. Link between the previous lesson and the present one.

III. Presentation of the new material :
(*a*) Demonstration of a movable pulley.
(*b*) Construction of a movable pulley.
(*c*) Properties of a movable pulley (Demonstration).
(*d*) Equality in the amount of the work performed when a movable pulley is used (Demonstration).

IV. Retention :
Solving problems on the movable pulley.

V. Home task.

Lesson No. 12

Topic : Laboratory work "conditions of equilibrium of forces on the basis of the lever and the pulley".

Aim : To teach students the skills of using rectilinear levers and pulleys, for verifying the properties of these machines.

I. The teacher's introductory talk on the laboratory work.
(*a*) The topic of the laboratory work.
(*b*) The purpose of the laboratory work.
(*c*) The requisite equipment.
(*d*) The method to check up the conditions of equilibrium of forces on the lever and the pulley.
(*e*) The experimental data table.
(*f*) Criteria of the report on the laboratory work.

II. Distribution of the sets of the devices among pupil's desks.

III. Execution of the laboratory work by pupils.

IV. Collection of the reports on the work.

V. The collection of the devices.

VI. Home task.

Lesson No. 13

Topic : Efficiency of simple machines

Aim : To clarify to pupils the concepts of the efficiency of simple machines.

I Questions to pupils on :

(*a*) Formula for calculation of mechanical work done against the force of gravity.
(*b*) Formula for calculation of work done against the forces of friction.
(*c*) Formula for calculation of power.
(*d*) The units of work and power.
(*e*) Solving problems on mechanical work.

II. Presentation of the new material :

(*a*) Unproductive processes during the working of the lever and the pulleys
(*b*) Useful work performed when a lever and pulleys are used.
(*c*) Total work done on the lever and the pulley.
(*d*) Concept of the efficiency of simple machines.
(*e*) Formula for calculation of the efficiency of simple machines.

III. Retention :

Solving problems on the efficiency of simple machines.

IV. Home task.

Lesson No. 14

Topic : The windlass.

Aim : To clarify to pupils the construction, the properties and the application of the windlass.

I. (*a*) What is the efficiency of a simple machine ? Why is the efficiency of any simple machine always less than 100% ?

(*b*) Solving problems on the efficiency of simple machines.

II. Presentation of the new material :

(*a*) Demonstration of a windlass.
(*b*) Construction of a windlass.

(c) Properties of a windlass (Demonstration)
(d) Application of the windlass in technology.

III. Retention :
Solving problems on the windlass.

IV. Home task.

Lesson No. 15

Topic : The inclined plane.

Aim : To clarify to pupils the construction, the properties and the application of the inclined plane.

I. Questions to pupils on :
(a) The properties of the windlass.
(b) The efficiency of simple machines.
(c) Formula for calculation of mechanical work.
(d) Solving problems on the windlass.

II. Presentation of the new material:
(a) Demonstration of an inclined plane.
(b) Construction of an inclined plane.
(c) Properties of an inclined plane.
(d) Amounts of work performed when an inclined plane is used (friction to be neglected).
(e) Method of measuring the efficiency of an inclined plane.
(f) Application of an inclined plane in technology.

III. Retention :
Solving problems on the uninclined plane.

IV. Home task.

Lesson No. 16

Topic : Laboratory work "determination of the efficiency of an inclined plane".

Aim : To teach pupils experimental skills required for determining the efficiency of an inclined plane

I. Teacher's introductory talk :
(a) Topic of the laboratory work.
(b) Purpose of the work.
(c) The requisite equipment.
(d) How to carry out the measurements and calculations.

(e) The experimental data table
(f) Criteria of the report

II. Distribution of the sets of the devices among pupil's desks.

III. Performance of the work by pupils

IV. Collection of the laboratory reports on the work done by pupils

V. Collection of the devices

VI. Home task

Lesson No. 17

Topic : Rotatory motion exemplified by belt and gear transmissions.

Aim : To clarify to the pupils the concept of angular and linear speeds

I. Presentation of the new material .

(a) Simple concept of the rotatory motion of a body
(b) Demonstration of rotatory motion
(c) Concept of angular speed.
(d) Concept of linear speed
(e) Belt transmission, its characteristics and application (Demonstration).
(f) Gear transmission, its characteristics and application (Demonstration).
(g) Friction transmission (Demonstration)

II. Home task.

Lesson No. 18

Topic : Concept of the kinetic energy of a body.

Aim : To clarify to pupils the simple concept of the kinetic energy of a body

I Questions to pupils :

(a) What is the linear speed of rotatory motion.
(b) What is the angular speed of rotatory motion.
(c) The construction and application of belt transmission
(d) Construction and application of gear transmission.
(e) Solving problems on transfer of motion

II Presentation of the new material :

(a) Definition of energy.
(b) Concept of the kinetic energy of a body (Demonstration).
(c) Dependence of the kinetic energy of a body on the speed of its motion (Demonstration)

(*d*) Dependence of the kinetic energy of a body on the mass of this body (Demonstration)

III Retention :

Solving problems on the kinetic energy of a body.

IV Home task.

Lesson No. 19

Topic : Simple concept of potential energy.

Aim : To clarify to pupils the concept of potential energy.

I Questions to pupils

(*a*) What is energy ?
(*b*) What is kinetic energy ?
(*c*) On what does the amount of the kinetic energy depend ?
(*d*) Solving problems.

II. Presentation of the new material :

(*a*) Concept of potential energy. Interaction of two bodies (energy of a body raised to a height) (Demonstration)
(*b*) Dependence of the potential energy of a body on the height and the mass of the body (Demonstration).
(*c*) Concept of the potential energy of the compressed spring (Demonstration)

III Retention :

Solving problems on the potential energy of a body.

IV. Home task.

Lesson No. 20

Topic : The law of conservation and transformation of energy (for mechanical processes)

Aim : To clarify the law of conservation and transformation of energy.

I Questions to pupils :

(*a*) What is kinetic energy ?
(*b*) What are the two types of potential energy which you know ?
(*c*) On what does the potential energy of a lifted body depend ?
(*d*) Solving problems on potential and kinetic energy.

II. Presentation of the new material ·

(a) Concept of total mechanical energy of a body (Demonstration).

(b) Discussion of the process of oscillation of a pendulum so far as its energy is concerned (Demonstration).

(c) Total mechanical energy of a body is a constant quantity (for purely mechanical processes).

(d) Discussion of the oscillations of Maxwell's pendulum.

(e) The change in the total mechanical energy of a body is equal to the work performed by this body.

III. Home task.

Lesson No. 21

Topic : Test on the topic.

Purpose : To check up the skill and knowledge of pupils on the given topic. It is necessary to prepare four variants of this test equally difficult and including physical problems. Each variant should have three problems

I. One problem on work or power

II. One problem on one type of simple machines

III. One problem on energy.

Teacher's Notes on Lessons

Lesson No. 1

The first lesson in a new big chapter should begin with the presentation of the teaching material. The checking of the previous knowledge should not be done and the teacher should give an introductory talk on the new chapter.

Introductory talk

Today we begin studying a big and important chapter and we shall continue it for seven weeks.

This chapter is called Work and Energy—Simple Machines. In dealing with this chapter we should get acquainted with such important concepts of physics as mechanical work, power, energy and efficiency of machines. You will learn the construction and the principle of working of such simple machines as the lever, the pulley, the windlass and the inclined plane. We observe how these machines perform work everyday and therefore it will be interesting to know how these machines work, in what way they help man to perform work which requires hard labour. Also we shall get acquainted with one of the most fundamental laws of nature, namely, the law of conservation and transformation of energy. Finally

it would be borne in mind that we shall deal with a great number of problems. Therefore, every pupil should, from the very first lesson, give his most serious attention to the topic and be able, as a result of the study of this topic, to acquire skills in solving such problems.

Presentation of the new material

We often hear the word 'work' in our daily life. By the study of this topic one should well understand that there is a difference between this word as used in everyday life and the concept of mechanical work used in physics Thus we may often hear the following statement:

The book-keeper is working at his annual balance-sheet or the engineer is working at another varient of a machine or the pupil is working out his home task etc

In all these cases we deal with different types of mental work. We also often hear the word 'work' when man performs muscular work. For instance, a man is holding in his hand or carrying on his back, some load without making a motion. They say that the man got tired of his work. In this case if the man is motionless they say that he performs the so-called physiological work making him tired.

The concept of work as used in physics is totally different from that used in everyday life, *i.e.*, it differs from the concept of mental or physiological work. That is then understood by mechanical work or simple work, from the point of view of physics Physicists say that mechanical work is performed provided a force is acting on a body and the latter is being displaced owing to the action of this force. Let us consider a few technological examples:

1. A moving motor-car performs mechanical work because in this case we have the action of the tractive force of the engine and the motor-car is displaced owing to this action. Consequently in this case we can say that the motor-car performs mechanical work.

2 A bullock moves a cart. In this case we have the tractive force exerted by the bullock and the displacement of the cart owing to the action of the muscular effort of the bullock.

3. A man is drawing a bucket of water from a well. In this case the man performs mechanical work because he exerts his muscular effort which displaces the bucket Now more examples of mechanical work performed can be given. In the above-mentioned examples we can observe that two conditions are indispensable for mechanical work to be performed. (i) an acting force or acting forces; (ii) displacement of the body under the impact of the force or the forces.

Now let us have a few demonstrations which will illustrate performance of mechanical work. Place on the table a block with a hook and load it with weights. By means of a thread connect the hook of the block with the demonstration spring

balance Let us displace by hand the spring balance together with the block Is any work performed in this case or not? Mechanical work is performed in this demonstration The question arises why it is performed in this demonstration. Work is performed in this demonstration because both the required conditions have been fulfilled:

(i) We have an acting force (ii) This force displaces the body Let us have another demonstration on the demonstration table. Let us place a stand and attach a fixed pulley to it. Then let us pass a thread over the pulley Let us attach a load to one of its ends and connect the other end with the demonstration spring balance. Now if we apply an effort (by hand) to the spring balance we shall raise the load to some height Is any mechanical work performed in this case? In this case mechanical work is performed because a force acts on the load and displaces it. Let us see if mechanical work is performed in the following demonstrations: place a wooden block on the demonstration table. Apply to this block a force vertical to the surface of the block by means of the demonstration spring balance and an effort of the hand. Is any mechanical work performed in this case? No mechanical work is performed. The question arises why no mechanical work is performed in this demonstration Mechanical work is not performed because in this case only one required condition, *i.e.*, a force which is not equal to zero, is fulfilled. But, this force does not cause any displacement Consequently displacement in this demonstration is equal to zero. If we represent work by W, the acting force by F and the displacement of the body by S, the result of the experiment may be represented as follows.

If $F \neq 0$, and $S=0$ then $W=0$.

Let us have another demonstration

Place an inclined plane which has a flat glass sheet at the base of it on the demonstration table. Observe the motion of a ball rolling down this plane. Is any mechanical work performed when the ball rolls along the horizontal part of the path? No mechanical work is performed. The question arises why in this demonstration no mechanical work is performed No work is performed because in this case the two conditions indispensable for work to be performed are not met. In this demonstration we have displacement of the body but we do not have any acting force which would cause such displacement. In this case the ball rolls because of inertia. Consequently the result of the experiment may be represented as follows:

If $F=0$ and $S \neq 0$, then $W=0$.

Thus from these examples and demonstrations we can draw the following conclusions.

Mechanical work is performed in all those cases where the following two conditions are present:

I. The acting force $F \neq 0$.

2. Displacement of the body under the action of this force $S \neq 0$.

or in short.

If $F \neq 0$ and $S \neq 0$ then $W \neq 0$.

Retention

1. Give examples of the performance of mechanical work when the force of gravity is overcome.

2. Give examples of the performance of mechanical work when friction is overcome

3. Is any work performed by the force of gravity acting on a load on the table?

4. Is any mechanical work performed by a man with a load on his back when he walks up a staircase?

5. Is any mechanical work performed by a motionless horse with a load on its back?

Home task.

Lesson No. 5

Topic : Concept of power.

Aim : To clarify to pupils the concept of the power of machines.

I. Questions to pupils.

II. Presentation of the new material.

We have considered the important concept of mechanical work and learnt how we can calculate the amount of work done against the force of gravity and against friction.

Very often in technology and in everyday life one has to compare the capability of various machines, devices and to compare the productivity of labour of various workers.

Let us see in what way comparison of this may be affected.

Suppose we have two lifting machines (lift or crane) and we want to compare the capability of these two machines

Let us assume that we know that one of the machines has performed the amount of mechanical work, $W=12{,}000$ kg wt m and the other machine's amount of work, $W=10{,}000$ kg wt m The question arises if it is possible, proceeding from these data, to find out which of the machines has more capability of doing work. It is not possible

It is not sufficient to know the work done only. It is because that we do not know how long these machines have worked. So, the capability of a machine

is understood as the amount of work performed in a unit of time. It follows that having only the data concerning the amount of work performed by these machines we cannot answer the question.

Thus to compare the capabilities of two machines it is not sufficient to know only the amount of the work performed by the machines but also the time taken for the performance of the works

The capability of a machine and the amount of work performed by the machine in one second is called the power of a machine Thus to calculate the power of a machine it is necessary to divide the amount of the work performed, by the time, during which this work was performed. Hence we can write as follows:

$$\text{Power of a machine} = \frac{\text{Amount of work done}}{\text{time taken}}.$$

If we represent the power of a machine by N, the mechanical work performed by W and the time by t we can derive the formula which helps us to calculate the power,

$$N = \frac{W}{t}$$

Consequently to compare the powers of two machines, one should know the amount and measure of the work performed by each of the machines and the time of performance. From the point of view of time factor, the power of machine is analogous to the speed of motion which you have already learnt studying kinematics.

Actually, if we want to compare the speed of the motion of two machines we cannot do this if we are given only the distances S_1 and S_2 covered by these machines, we cannot also do this if we know the times of their motion alone *i e*, t_1 and t_2

So the speeds of motion can be compared only on the basis of the distances covered in a unit time by each machine. By analogy with speed, one can say that power represents the speed of performance of mechanical work by a machine. Such machines as cranes, locomotives, electric engines, motor-cars, etc., are supplied by the plants which produce these machines, with the specifications, in which the principal data concerning these machines are given One of the important characteristics of a machine is its power. Let us see how we can calculate the power experimentally using the formula $N = \frac{W}{t}$. Since we have introduced a new physical quantity—power, it is necessary to find out in what units it is measured. This can be done easily with the formula for power, given above

We have already learnt that mechanical work can be measured in kg wt m or in joules. The time in this formula is given in seconds Hence, it is clear that power can be measured in $\frac{kg\ wt\ m}{sec.}$ or $\frac{joule}{sec.}$. The power of a machine

is 1 $\frac{kg\ wt\ m}{sec.}$ when it performs the work of 1 kg wt m in 1 second. In addition to this unit of Power, physicists use another unit of power $\frac{joule}{sec.}$. This unit is also called watt. The machine performing the amount of work of 1 joule in 1 second has the power of one watt. In technology bigger units of power are used 1 hectowatt=100 watts or 100 joules per second and 1 kilowatt=1000 watts or 1000 joules per second Sometimes we use the old unit of power, H P 1 H.P.=76 $\frac{kg\ wt\ m.}{sec.}$ It means that the machine performing 76 kg wt m of mechanical work in 1 second has the power of 1 H P. If a horse works for longer period, power does not exceed 0 5 H P Consequently, the name H.P. chosen as a unit of power is not a very lucky one. The range of power of a man if he works for longer period, is 0.05 to 0 1 H P Your textbooks contain a table of powers of those modern machines, which is used most widely.

From the formula of power, $N = \frac{W}{t}$, it follows that given the power of the machine and its time of performance one can calculate the work which would be performed by the machine

Let us place a stand on demonstration table and to the upper part of the stand clamp a fixed pulley. Pass a thread over the pulley and fasten a load of 300 g wt to one free end and a demonstration spring balance to the other. Near the stand, fix a vertical demonstration ruler. Raise the load uniformly to a certain height, noting simultaneously the time during which we raise the load by means of a metronome Given the weight P=1000 *g wt* and the height=50 cm and the time t=2 seconds, we can calculate the power developed during the process. For this purpose, let us first calculate the amount of the mechanical work performed

$$W = 1 \text{ kg wt} \times 0\ 5 \text{ m} = 0\ 5 \text{ kg wt m}$$

$$N = \frac{W}{t} = \frac{0\ 5 \text{ kg wt m}}{2 \text{ sec}} = \frac{0\ 25 \text{ kg wt m}}{\text{sec.}}$$

III. Home task

List of demonstrations on the topic

"Work and Energy"—Simple Machines

1. Demonstration of conditions under which mechanical work is performed.

(*a*) If there is an acting force but there is no displacement of the body under the impact of this force, work is not performed, *i e.*, when $F \neq 0$ and $S=0$ then, $W=0$,

(*b*) If a body is displaced but there is no force which would cause this displacement, work is not performed, *i e*, when $S \neq 0$ and $F = 0$, then $W = 0$.

(*c*) If a force acts on a body and displaces it, mechanical work is performed, *i e*, when $F \neq 0$ and $S \neq 0$, then $W \neq 0$

2. Demonstration of measuring the amount of work performed to overcome the force of gravity.

3. Demonstration of measuring the amount of work performed to overcome the force of friction.

4. Demonstration showing that the amount of work performed to overcome the force of gravity is more than the amount of work necessary to overcome the force of friction, provided the same body is displaced through the same distance.

5 Demonstration of measuring the power developed when a body is raised to a certain height.

6. Demonstration showing that every moving body has certain amount of kinetic energy.

7. Demonstration of the dependence of the kinetic energy of a moving body on the speed of the motion of the body.

8. Demonstration showing that every body raised to a height has a certain amount of potential energy.

9. Demonstration showing that the amount of potential energy of a body raised to a height depends on the weight of the body and the height achieved.

10. Demonstration showing that a compressed spring has a certain amount of potential energy.

11. Demonstration showing transformation of kinetic energy into potential energy and *vice versa*.

12. Demonstration of two types of the lever

13. Demonstration of the conditions of equilibrium of forces on the example of the lever

14. Demonstration of the equal amounts of work when the lever is used.

15. Demonstration of the technological application of the lever in the devices given below.

(*a*) Performance of a spanner.
(*b*) Performance of scissors.
(*c*) Performance of iron cutting scissors.
(*d*) Performance of the pliers.
(*e*) Performance of the wire cutter.
(*f*) Performance of a model pump.
(*g*) Performance of a model lifting gate of the railway crossing.
(*h*) Performance of a stick for carrying a load on the shoulder.

16 Demonstration of the properties of a fixed pulley.

17. Demonstration of the properties of a movable pulley.

18 Demonstration showing that application of a movable pulley does not give any gain in force.

19 Demonstration of the properties of a windlass.

20. Demonstration of the properties of an inclined plane.

21. Demonstrations of three types of transmission of motion

(*a*) Belt transmission

(*b*) Gear transmission

(*c*) Friction transmission.

CHAPTER IV

Elementary Thermal Phenomena

I. *The significance of the chapter*

This is the first chapter in the course of physics devoted to the thermal phenomena. In the course of physics for class VII, the study of thermal phenomena is subdivided into following three chapters:

1. Elementary thermal phenomena.
2. Heat and work.
3. Transition of substance from one aggregate state into another.

The present chapter is of great significance and helps to understand the importance of thermal phenomena in everyday life and technology. This chapter includes one *small sub-topic* which is introductory to the whole thermal phenomena. This *sub-topic deals with* the basic idea of the structure of substance This *small sub-topic* is very important.

The informative value of this topic is due to the fact that in order to study heat after having studied the simplest type of motion, namely mechanical motion which is second in complexity, *i.e* the motion of molecules. Dealing with the topic pupils get acquainted with a wide range of natural phenomena, namely, the change in the size of a body when heated or cooled, the three forms of heat transfer : heat conduction, convection and radiation Finally, this topic is important for it shows the various applications of these phenomena in technology.

II. *The content of the chapter*

1. Molecules and their motion; diffusion
2. Inter molecular forces in solids , liquids and gases.
3. Expansion of solids, liquids and gases (examples from technology).
4. Temperature, thermometers and their construction, clinical thermometers.
5. Heat conduction in solids, liquids and gases. Application in technology of good and bad conductors of heat. Convection in liquids and gases. Thermal radiation and thermal absorption. *Anomalous* expansion of water.

III. *The analysis of the key concept of the chapter*

1. The fundamentals of the molecular kinetic theory of the structure of substance.

Very long ago, *i.e.*, about the fifth century B.C. the idea was formed that all the bodies which surround us consist of tiny particles which could not be observed directly. It was during the last 120 years, however, that the modern theory of atoms and molecules was evolved and experimentally proved.

Molecules are tiny particles of matter of which various substances are made In some cases, for example, in metal, in inert gases (helium, Argon and so on), tiny particles of substances are individual atoms In other case these particles consist of several atoms and they are called molecules Molecules of hydrogen, oxygen consist of two atoms, carbon dioxide molecule of three atoms, and so on. Numerous discoveries made in physics and chemistry confirm that atoms are tiny particles of substances, "the bricks of the universe". From an important law in chemistry, the law of multiple proportions, it follows that when two elements form several compounds, the masses of one of the elements combining with a given mass of the second element to form different compounds, bear an integral ratio. Thus, for instance, nitrogen and oxygen form five compounds, N_2O, NO, N_2O_3, NO_2 and N_2O_5. Here in all these compounds, the different masses of oxygen combining with a given mass of nitrogen are in integral proportion such as 1: 2: 3: 4: 5. There is not a single example in which masses of two elements forming such compounds have not the ratio of whole numbers. That is why it is possible to conclude that atoms are the tiniest particles of which all substances in nature are made. The idea of the molecular structure of bodies, *i.e.*, that all bodies in nature are built of molecules does not at the first instance agree with our everyday experience since we cannot observe these individual particles. We regard them as compact bodies. However, this is accounted for by the small size of molecules. Even by using the best optical microscope, which enables one to identify the objects the size of which is not less than 0.0002—0.0003 cm, it is impossible to see the biggest molecules. But quite a number of indirect methods have made it possible not only to prove the existence of molecules and atoms but even to find out their sizes. Thus the hydrogen atom may be regarded as 1.2×10^{-8} cm in size; the size of the molecule of hydrogen *i.e.*, the distance between centres of the two atoms, which it consists of, is 2.3×10^{-8} cm. The mass of the hydrogen molecule is 3.3×10^{-24} gram.

Dealing with the sizes of atoms and molecules one should bear in mind that at the initial stages of our discussion of the structure of substances, we regard molecules and atoms as tiny balls. Therefore, when we speak about the size of atoms and molecules we mean the diameter of such balls.

Only a few years back due to the development of electronics it has been possible with the help of the electron microscope to photograph some larger molecules. Much experimental data show that molecules in all substances, solids,

liquids and gases are in constant motion. For example, everybody knows well the phenomenon of diffusion, *i.e.*, the phenomenon in which two substances mix with each other by themselves In diffusion a substance spreads in every direction as well as upwards *i e*, against gravity. The phenomenon of diffusion shows that molecules are in constant motion and this motion takes place in different directions This motion is called molecular thermal motion The general character of molecular motion is similar for gases, liquids and solids In each case the motion is random *i e.*, the speeds at which the molecules move have no predominant direction and are spread at random in all directions. Because of the collision of molecules, their speed keeps changing both in terms of direction as well as magnitude. Therefore, the speeds of molecules may differ considerably. At any instant, there are molecules in a body which move extremely fast as well as molecules which move relatively slow However, most of the molecules move at speeds which differ very slightly from some average speed depending on the nature of the molecule and its temperature.

The phenomenon of diffusion indicates not only the motion of molecules but also shows that every body is built of molecules which are not very densely "packed" *i.e.*, *in other words* there is some space between them. Finally, between the molecules there exist certain forces of interaction. These forces, known as molecular forces, manifest themselves in mutual attraction and mutual repulsion. The character of the interaction of molecules depends on the distance separating the molecules. With the decrease in the distance between the molecules the forces of repulsion increase faster than the forces of attraction.

Thus the main conclusions of the molecular kinetic theory of substances are as follolws·

1. Every body consists of tiny particles that are called molecules.
2. The molecules in any body are in constant motion.
3. Between the molecules of a body there are gaps (space) separating the molecules from one another.
4. Between the molecules there exists a force of interaction that manifests itself in mutual attraction and mutual repulsion

2. *Thermal Expansion of Bodies*

Simple experiments and observations show that when the temperature of a body rises, it expands slightly in size whereas when it is cooled the body contracts to its original size. Thus, for instance, a bolt heated considerably will not fit into the screw whereas it would easily fit when it is cooled. In hot weather telegraph wiring sags noticeably compared to that during winter. If a *homogeneous* body is heated uniformly it will keep its shape, though it expands A different situation will arise when a body is heated non-uniformly. When bodies are heated non-uniformly, there appear in them some strains which may damage it completely if the

tensions are excessive. Thus thick glasswares will have tensions immediately after it is filled with hot water and it would sometimes break This happens because the inner parts will get heated and expand first, stretching at the outside surface of of the vessel. This strain on heating can be avoided if the vessel has very thin walls so that the heat spreads quickly throughout the whole substance (chemical glassware).

Different solid materials have different linear expansions when temperature rises to the same extent The deformative tensions arising in solids owing to thermal expansion may be very considerable. This factor should be considered in many branches of technology. There have been cases when some parts of iron bridges rivetted during day time break their rivets during night time on account of the change in length, due to the fall in temperature. To avoid this, measures are taken so that parts of a construction could expand and contract freely with change in temperature. For instance, when rails are laid, spacing is left between the junctions. Iron steam piping is always provided with bends in the form of loops (compensators).

What causes the expansion of solids? The teacher knows that the atoms and molecules in crystals are located at the joining points of the lattice They oscillate in every possible direction around some position of equilibrium near the lattice joints. With an increase in temperature the range of oscillations of the particles increases and mutual *repulsion will exceed mutual attraction.* Therefore, when heated, the average distances between the particles of a body increase which manifests itself in the expansion of bodies.

We cannot speak about linear expansion of liquids, for liquids have no definite shape Expansion in volume of liquids can however be easily observed. Fill a flask with coloured water or any other liquid and insert a cork with a tube passing through it so that the liquid should enter the tube If you immerse the flask in hot water, the level of liquid in the tube will first momentarily come down and then will start rising. The lowering of the liquid level at first indicates that the *vessel* first expands while the liquid has not yet become warm. Then the liquid also gets warm. The increase of its level shows that the liquid expands more than the glass. Different liquids expand differently when heated; kerosene, for instance, expands more than water.

If a liquid is heated in a closed vessel thus preventing expansion, it would experience, like solids, large tensions which are transferred to the walls of the vessel and are capable of breaking the latter. That is why the arrangement of pipes in central heating system are always provided with an expansion tank which is connected to the upper part of the system, having a let-out into the atmosphere

The substance which is abundant on the surface of the earth, namely, water has a peculiarity owing to which it behaves unlike most other liquids. It expands only when heated above 4 °C. Within the range of 0 °C to 4 °C, the volume of water decreases on the contrary, when heated. The water has maximum density

at 4°C. This can be easily observed from the formula of density $D = \frac{m}{v}$. With the minimum value—v_{min}, the density will be maximum because the ratio $= \frac{m}{V_{min}}$ is maximum when the denominator is minimum in case of water at 4°C.

The peculiar expansion of water is of great significance for influencing the *earth's climate*. The greater part of the earth's surface, about 79%, is covered with water. The sun's rays falling on the water surface are partly reflected from it and partly penetrate into the water and heat it. In colder regions if the temperature of the water is low, the layers heated (for instance at 2°C) are denser than the cooler layers (for instance at 1°C) and, therefore, move downwards. These are replaced by the cooler layers which in their turn become heated. Thus a constant change of the layers of water takes place which contributes to a uniform heating of the whole mass of the water until it attains the temperature at which water has maximum density. On further heating the upper layers become less dense and therefore remain above

Owing to this, the large masses of water are heated by sun's rays easily to the temperature of the maximum density of water. Further, heating of the lower layers goes on very slowly. On the contrary, the cooling of water to the temperature of maximum density occurs relatively easily and then the process of cooling slows down. All this accounts for the fact that deep water basins on the surface of the earth have, starting at some depths, right up to the bottom, a temperature close to the temperature of maximum density (3°—4 °C) The upper layers of sea water in hot countries can have the temperatures which are much higher *e.g.*, 30°—35 °C.

The cause of expansion of liquids is the same as that of solids. Liquids expand more than solids because the forces of molecular attraction in liquids are less than those in solids.

Gases like solids and liquids expand when heated. Thermal expansion of gases as well as of liquids is due to the increase in their volumes Unlike solids and liquids different gases when heated increase their volume equally and this increase does not depend on the nature of the gas (ideal gases).

III. *Various Processes characterised by Transfer of Heat*

When no work is performed, the transfer of heat takes place in a definite direction. The internal energy of a heated body increases whereas the internal energy of a cooled body diminishes.

The greater is the difference in the temperatures of two bodies in contact the more intensive (under similar other conditions) will be the process of heat transfer from a hotter body to a colder body. When the temperatures of the two bodies become equal, transfer of heat stops and the so-called thermal equilibrium occurs. Let us see what processes lead to the temperatures becoming equal.

(a) Thermal Conductivity

When we heat cold water in a pot, placed on a hot stove, heat transfer occurs through the walls of the pot. Property of bodies to transfer heat is called Thermal Conductivity. On what factors does the amount of the heat transferred through the walls depend? Firstly, it depends on the surface area of the wall. The water in a pot with a wide bottom becomes heated faster than in a pot with a smaller area of the bottom surface. Experiment will easily show that the amount of heat transferred in unit time through a wall at a certain difference of temperatures depends on the thickness of the wall. The thicker the wall the less is the amount of heat transferred. Finally, transfer of heat depends considerably on the material of which the wall is made. Good thermal conductivity is possessed by all metals whereas liquids, and more so the gases, are very poor thermal conductors.

(b) Convection

Besides thermal conductivity, heat transfer in liquids and gases often occurs because of convection *i.e.*, the process of heat transfer, when the heated parts are mechanically displaced. Very frequently when a liquid or 'a' gas comes in close contact with the walls of the container whose temperature is higher than that of the liquid or the gas contained in it a convection current is set up in the heated liquid or gas. Hot layers move upwards and the cooler layers move downwards. This happens because of the decrease in the density of the liquid or the gas when their temperature rises.

Evidently convectional currents in liquids and gases develop more easily if their co-efficient of expansion is greater. Viscosity of liquids and gases is also important. More viscosity will evidently hinder the development of convectional currents. In very narrow layers, for instance, in a layer of air between two closely situated window panes, convectional currents are weak. If convectional currents develop, they contribute largely to quick heating of the liquids and gases. When there is no convection, the heating of liquids and gases is very slow because of their low value of thermal conductivity. Convectional currents in the atmosphere not only play a great role in heat transfer but also set up the winds. *Winds cause sea currents and waves*; they rotate the blades of wind-operated engines. Convectional currents in the atmosphere cause constant displacement of the air owing to which the air at different places of the earth's surface has almost the same composition.

(c) Radiation and Absorption of Radiation

Apart from heat transfer through thermal conductivity and convectional current, an important part, in nature and technology, is played by heat transfer due to radiation and absorption of radiation. When we bring the hand to a hot iron even not so close, we feel warmth. The iron emits heat rays and therefore gets cooler, whereas the hand absorbs them and becomes heated. These

rays are not other than electromagnetic radiations. One of the peculiar characteristics of heat transfer by means of radiation is that it can take place in vacuum For example, the huge amount of heat the earth receives from the sun's rays is transferred exclusively by means of radiation and absorption of radiation.

IV. *The Methodological Analysis*

It was already mentioned that in order to make the pupils understand well the entire chapter on heat and the first topic, namely, elementary thermal phenomena, it is advisable to begin this topic with a review of the fundamentals of the molecular structure of matter with which pupils were acquainted in the course of physics for class VI. The specific feature of this topic from the point of view of the methodology of its study is that all the questions of this topic are studied only qualitatively. This is accounted for by the difficulties in the mathematical presentation of the topic through analytical method. The quantitative aspect of this topic is discussed at the second stage of instruction in class IX. Since the analytical method cannot be used for presentation of this topic in class VII, demonstration as the basic method to be used becomes essential. A number of such demonstrations can be performed while dealing with this topic The teacher's task is to select from these the simplest and the most convincing demonstrations. It is important to think over the methods and techniques of performing each demonstration experiment on the basis of these experiments, the deriving of certain properties and characteristics. This topic, namely, simple thermal phenomena, consists of two sub-topics:

1. Expansion of bodies on heating.
2. Forms of heat transfer.

The first sub-topic, namely, expansion of bodies on heating, can be discussed in the following sequence: Expansion of solids, liquids and gases. Instances of thermal expansion of bodies are widely observable in nature and technology. It is advisable, therefore, to begin the discussion of this question by analysing such instances given by pupils and based on their everyday observations. After that a simple demonstration with Gravezand's Ball can be shown. The experiment described in the textbook with *a rod,* one end of which is fixed and the other end rests on a horizontal needle, is also a simple one. On being heated with a spirit lamp, the rod expands and rotates the needle with a light arrow attached to it. It is important to help pupils to form the idea of the unequal expansion of different metals. It is desirable, therefore, to perform experiments not only showing the effect of thermal expansion but also the respective amounts of expansions. To ensure complete comprehension of the phenomenon of expansion of solids on heating and their contraction on cooling, pupils with the teacher's help should solve some interesting qualitative and experimental problems.

The same sequence may be maintained while discussing the questions of expansion of liquids and gases. After the discussion of expansion of different bodies on heating, we pass over to the question of measuring temperatures. Pupils have the same idea of temperature which they have formed from everyday experience. The teacher's task is therefore to help them to acquire skills in measuring temperature.

Temperature is a quantity characterising the thermal state of a body. If the temperatures of two bodies are equal the bodies are in the same thermal states.

This approach in defining temperature may be preserved in the elementary course of physics.

Pupils are first told that bodies can be heated to a different extent. For example, water in a vessel can be called warm and hot. But to form a more exact judgment about it, it is necessary to find such an identifying feature or such a property of the body which would clearly indicate to what extent the body is heated. Expansion of bodies on heating can serve as such distinguishing feature. The greater the extent to which a body is heated the more will be the expansion in its volume and more intensive will be the chaotic motion of the molecules. Thus by a change in the volume of body on heating, we can judge the intensity of its molecular motion or its temperature After that the experiment with a flask (figure 38) is shown and the conclusion is drawn that the temperature of the water in the flask can be judged by the height to which it rises in the tube. If the liquid

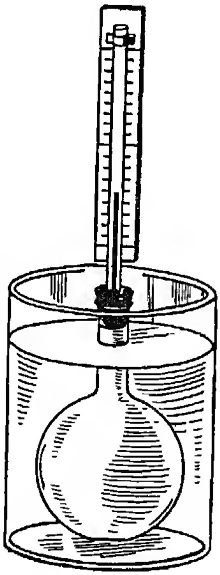


Fig. 38

in the flask has the temperature of the surrounding medium the height of the liquid in the tube is the indicator of the temperature of the medium (air, water, etc) as well. Thus, a flask with water and a narrow tube attached to it can serve as a simple "thermometer" Then the teacher passes over to the discussion of the construction of various thermometers and their practical applications. Out of the various types of thermometers it is advisable to examine laboratory, clinical, maximum and minimum thermometers. Then the teacher should demonstrate how it is possible to graduate a thermometer. A laboratory thermometer whose scale is covered with white paper can be used for this purpose. First the thermometer is put in melting ice and the level of the liquid in the thermometer is marked. This temperature is accepted as 0° in the Celsius scale. Then the thermometer is placed in the vapour of boiling water and again the level of the liquid is marked. This temperature is accepted as 100° in the Celsius scale. With the two main points of the Celsius scale on the strip of the paper, it is necessary to divide the distance on the scale into equal parts to obtain smaller grades on the scale. After that the self-made scale must be compared with the commercial one.

Pupils should be made to understand the following points while making use of a thermometer:

(1) Every thermometer is intended for measuring temperatures only within a certain temperature range. One cannot, therefore, use a thermometer if the temperature to be measured is below or above the minimum or maximum range valid for the given type of thermometer.

(2) Reading should be taken after sometime during which the thermometer acquires the temperature of the medium being measured

(3) When the temperature is measured, the thermometer should not be removed from the medium before noting down the temperature.

(4) The observer's eye should be on the level of the upper end of the liquid pile inside the thermometer. Pupils should be told about some examples of temperatures which we come across in everyday life and technology. Many mammals have the normal temperature from 35—45.5°C. The temperature of a healthy man is 36-37°C. The temperature of birds 39.5—44°C. Maximum temperature on the earth 58°C was registered in Tripoli and the lowest −88.3°C in the Antarctic. The tungsten filament in a bulb filled with a gas becomes heated to 2250°C and the temperature of the sun's surface is about 6000°C.

After that, the simple laboratory work, study of the construction of the thermometers and measuring temperature with them can be done. After doing this work, pupils should examine qualitatively the scales of the given thermometers and measure the room temperature and the temperature of water in a vessel. It is desirable also to organize an excursion to a weather forecasting station and acquaint pupils with measuring temperatures, with different thermometers The first subtopic is completed by discussing thermal expansion of bodies in nature and

technology. With some examples of thermal expansion of bodies in everyday life and technology, pupils are introduced to the first lesson of this sub-topic. However, since this phenomenon is very important in many branches of technology, a special lesson as its applications should be given

In the first place, pupils could be shown how tremendous forces develop when solids expand or contract because of thermal changes. For this purpose the well-known device suggested by Tyndal may be used. In this experiment a heated rod clamped with a screw in the base plate breaks when it cools a cast iron rod inserted in the orifice at its end. Pupils's attention should be drawn to the fact that the huge force developed due to expansion, causes the destruction of mountain rocks especially if these are not homogeneous such as granite Some scientists explain the formation of craters on the lunar surface etc. by thermal expansion.

Instances of thermal expansion in technology are numerous Here one can speak about laying the rails of a railway, thermal compensators of water heating systems, construction of bridges, electric wiring, etc. Once these examples are discussed pupils should be shown how thermal expansion is made use of in the following automatic devices :

1. *The Contact Thermometer* (figure 39), when acidulated water in a flask is heated, the liquid goes up and forms a contact between the two ends of insulated wires from the ends of which insulation was removed and which were put in a glass tube.

2. *The Bimetallic Signalizer* —First pupils are shown how a bimetallic plate, when heated in the flame of a spirit lamp (figure 40), changes its initial shape. Then closing a circuit with the help of a bimetallic plate, switching on some apparatus, for instance, a lamp is demonstrated.

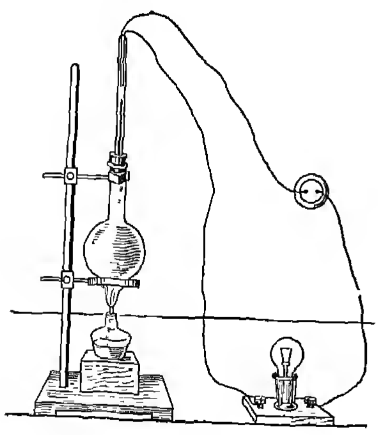


Fig. 39

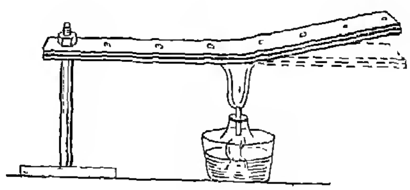


Fig. 40

A signalizer assembled according to the scheme shown in figure 41 can be demonstrated. At room temperature the lower contact can be closed. When a device is switched on, the bimetallic plate heated by the lower lamp bends and breaks the contact Bending further owing to thermal inertia the plate closes the upper contact which is situated nearby and switches on the upper lamp On the contrary, when the plate is cooled, the lower lamp is switched on whereas the upper lamp is switched off and so on.

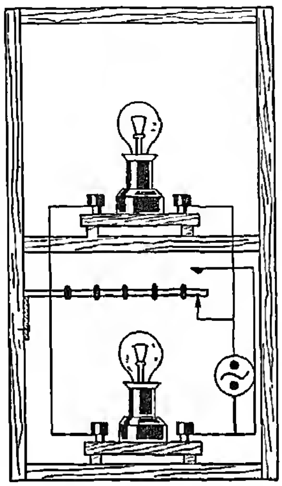


Fig. 41

II. *Transfer of Heat*

The content of this sub-topic in fact makes it possible for pupils to understand the second law of thermal dynamics which asserts the impossibility of spontaneous transfer of heat from a cooler body to a warmer one. Therefore to the fact that the transfer of heat always occurs in a certain direction : from a body at a higher temperature to a body at a lower temperature, the pupil's attention should be drawn Before presenting the content of this sub-topic, the main points of molecular kinetic theory should be revised. This approach makes it possible for pupils to learn more profoundly.

After that, various forms of heat transfer are discussed. The following sequence is observed in the textbook : thermal conduction, convection and radiation. Summing up ideas formed by pupils and the demonstrations shown (the list of which is given at the end of the chapter) the teacher establishes the fact of heat transfer from one part of a solid body to another. Heat transfer by means of conduction can be explained to pupils in the following way: When a body is

heated the speed of the molecules increases. This intensified motion of the molecules of one part of the heated body is transferred to the molecules of the adjacent parts. This gradual process results in higher speed of the molecules inside the body and consequently increases the temperature of the whole body. This process of heat transfer is known as conduction. After that, on the basis of the discussion of examples from everyday experience of pupils and simple and convincing demonstrations, the concept of good and bad heat conductors and their application in technology is introduced. To achieve clear understanding of the part played by good and bad conductors, qualitative and experimental problems should be solved by pupils.

2. *Convection*

Presentation can begin with performing a problem experiment* (figure 42), arranging in the given way two glass tubes with water over the flame of a spirit lamp. Here the readings of one thermometer (the left one in the picture) will not change whereas those of the other thermometer (the right one in

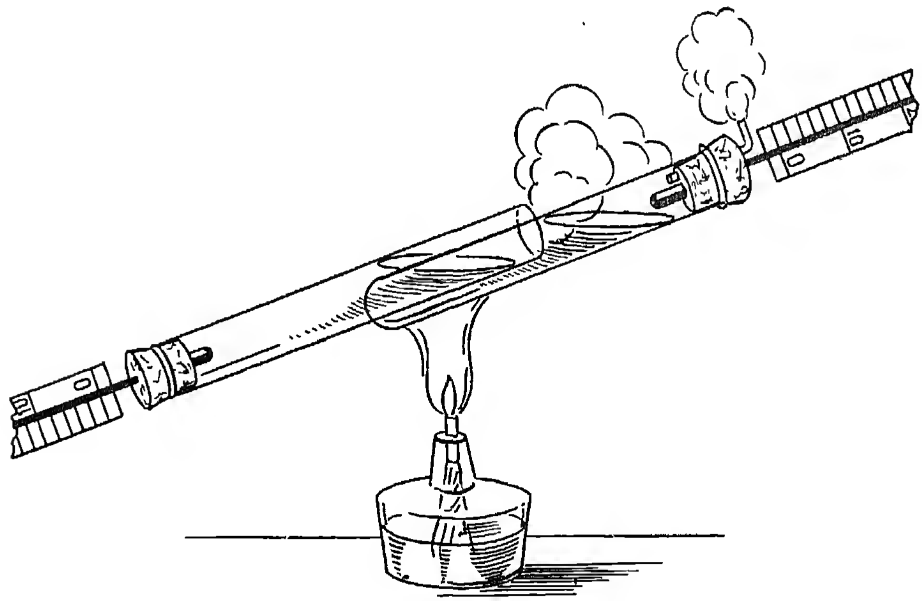


Fig. 42

*By problem experiment is meant an experiment before the teacher has given explanation which the students will be asked to explain after they have observed it.

the picture) will. Begin discussions with pupils: Why in one case the water conducts heat well and in the other badly? By means of discussion, it is clarified that in the left hand side tube the readings of the thermometer do not change for water is a bad thermal conductor. In the second case when water is heated its expansion takes place and its density decreases and consequently under Archimedes Law the layers of water that are heated go up and transfer the heat registered by the thermometer. For pupils to see the upgoing warm currents, it is necessary to perform the following experiment.

If a round-bottomed flask filled with water is taken, on the bottom of which there is a small crystal of potassium permanganate and is fixed to a stand, the convectional currents will be seen to colour the water if the water is heated slowly.

To demonstrate conductivity and convection in gases, an experiment similar to the one shown in picture 10 (textbook) can be performed. Test tubes with air can be used for this purpose. After that with the help of paper rotating wheels and smoke, the teacher can demonstrate the upgoing currents of air above a heater. Pupils will listen with interest to the teacher telling them that the mass of one cubic metre of water at 100°C is 42 kilograms less than at 0°C. The mass of one cubic metre of water at 100°C is almost 1.04 times less than at °0C. Consequently convection in gases is also explained by Archimedes Law. As an example of convection in nature, the blowing of day and night breezes may be given while in technology the formation of the draught in chimneys, convection in water heating, water cooling of internal combustion engines etc., may be pointed out. As in case of conductivity, after explaining the mechanism of heat transfer by convection, it is necessary to solve with pupils a sufficient number of qualitative problems having great practical significance.

3. *Radiation*

In nature we find some examples of heat transfer from luminous bodies

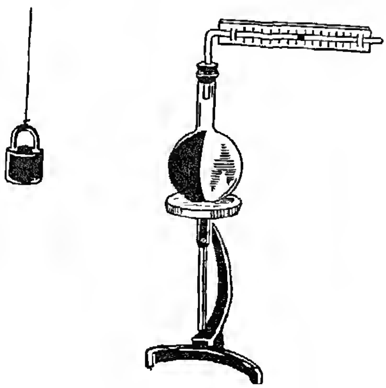


Fig. 43

by means of radiation. Pupils know that the main source of light and heat for the earth is the sun, situated at a great distance (150 million kilometres). However, most pupils are unaware of the fact that there exist invisible thermal radiations which are emitted by any heated body. The nature of the phenomenon is established by the experiment with a hot body and a thermoscope (figure 43).

The question arises :What causes the heating of air in the flask of the thermoscope? Heat transfer from the hot body to the thermoscope could not have taken place by means of conduction or convection. Consequently to explain the result of the experiment, one had to assume that in this case heat is transferred from the heated body with the help of invisible thermal rays.

This experiment is repeated after turning the thermoscope to the hot body so that the white side faces it and it is observed that white surface absorbs rays less than black.

The teacher then proceeds to formulate the concept, difficult for pupils to understand that black bodies at equal temperatures not only absorb more heat than white bodies but also radiate more heat. For this purpose the experiment is performed with the vessel A (figure 44) one wall of which is covered with the black paint and the other with white paint. The vessel is filled with hot water and near it are placed two heat absorbers B and C connected with different manometres.

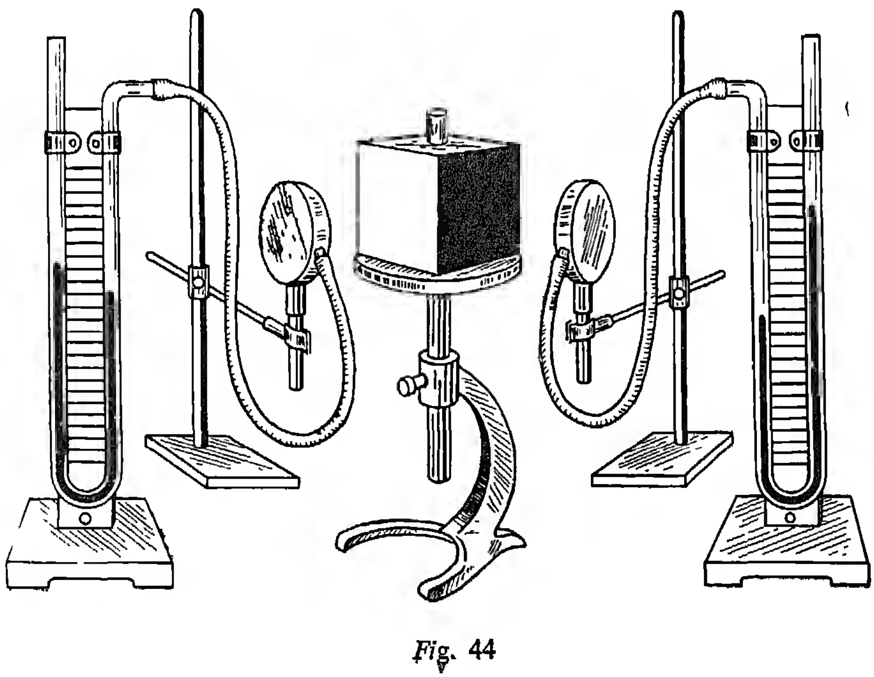


Fig. 44

The discussion of the phenomenon of radiation is ended by solving qualitative problems of practical importance and explaining natural and technological phenomena.

I. *Problems on Thermal Expansion of Bodies*

1. Why is it necessary to avoid fixing the telegraph lines lightly between poles when telegraph communication lines are laid?

2. Why do precision measuring instruments have indications of temperature on them (normally 20-30°C)?

3. Why is it necessary to avoid filling the tank with petrol up to the top of the tank?

4 Why does the level of water in a bottle go down when the water is cooled considering that the bottle also contracts?

5. Two vessels with pipes are filled, one with water and the other with kerosene, to the level of the dotted line on the screen (figure 45). Then the vessels are placed in hot water. Which of the vessels contains water and which kerosene?

6. Figure 40 represents two plates—copper and iron—fixed together. The plates are heated. Find out which of them is the copper plate and which one is the iron plate.

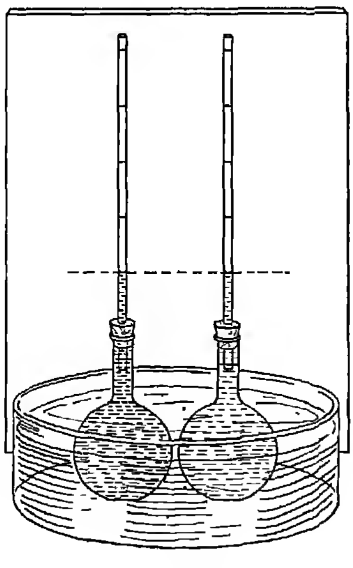


Fig. 45

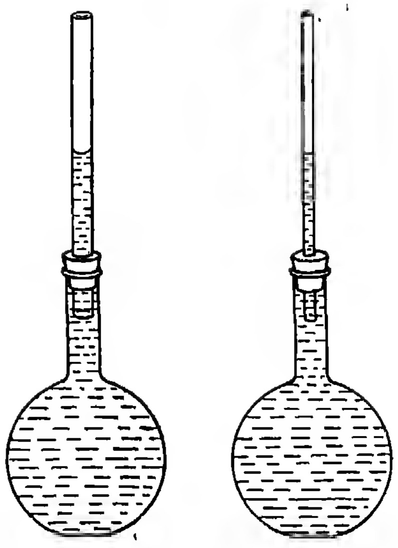


Fig. 46

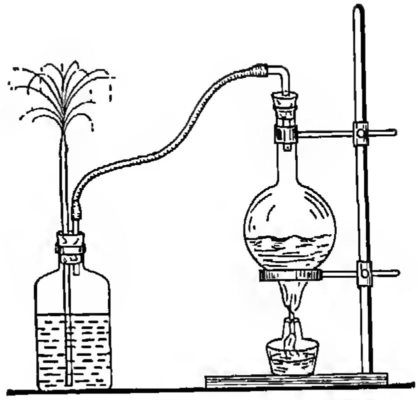


Fig. 47

7. In what way will the level of water in glass tubes change if the tubes are connected with vessels of equal capacities (figure 46a, b). The condition is that water in the vessels is heated to the same temperature.

8. Explain the action of the fountain represented in figure 47.

9. Why does the level of mercury in the medical thermometer not go down immediately after it was removed from under the armpit?

II. *Problems on Various Forms of Heat Transfer*

1. Why don't you burn your fingers when you hold a burning match?

2. Which one of these is the best thermal insulator: brick, glass or concrete?

3. In what way is it possible to keep warm the inside of Eskimos' huts made of ice?

4. Why does a mirror become heated so little?

5. Why do people wear light clothes in summer?

6. Why does the dirty snow in towns melt faster than clean snow in the fields or on the mountains?

7. Why are the radiators of central heating placed in the lower part of the room and not in the upper part?

8. Why are the handles of hot water tanks' top made of wood?

9. In cold places, pipes of water system are wrapped up in thick felt and bound with wooden boards. Why is it done?

10. Air conducts heat badly. Why then objects do not cool in the open air?

11. Why are the chimneys of plants and factories made so tall?

12. Why do window shutters help to keep the house Warm?

13. Why in winter are the shutters of fireplaces closed only after the wood has burnt out?

14 Why is the underground cabin the coldest place in the house?

15. Why do glasses with thick walls crack more often than those with thin walls?

16. If you drink tea from an aluminium jug you will burn your lips, whereas the same tea will not burn lips if you drink from a jug made of porcelain. Why?

17. Experienced house-wives put a tea spoon into the glass before pouring boiling water in it. Why?

18. Burning coal put on metal is quickly extinguished whereas on a wooden board the same goes on smouldering. Why?

19. A piece of paper wrapped tightly around a copper rod will not burn if it is kept in the burner's flame for a short time. If the copper rod is replaced by a wooden one the paper will start burning quickly. Why?

20. Which soil will be warmed by the sun more quickly—wet soil or dry soil?

21. Animals having hair on the bodies shed the hair in spring while in autumn the hair grows again. What is the importance of this for the animals?

22. Man does not feel that the air is cool if the temperature is 20° C whereas in water he feels cold at the temperature of 25° C. Why?

23. Why does a strip of paper over a burning candle go up quickly?

24. When does a tea-pot with boiling water cool faster when the pot is on ice or when ice is put on the tea-pot cover?

25. There are holes in the lower and upper parts of projectors and movie cameras. Why?

THE TOPICAL PLAN
(All in all 15 lessons)

No.	Date of the lessons	Topic	Methodological work	Demonstration	Home task
1	2	3	4	5	6
1.		Thermal phenomena.			
2.		Fundamentals of molecular kinetic theory of substances.			
3.		Expansion of solids on heating			
4.		Expansion of liquids and gases on heating.			
5.		Concept of temperature and methods of measuring it.			
6.		Construction of thermometer.			
7.		The clinical thermometer; Maximum and Minimum thermometer.			
8.		Applications of thermal expansion in technology.			
9.		Transfer of heat, heat conduction.			
10.		Examples of use of thermal conductivity in technology. Solving problems on conductivity.			
11.		Convection.			
12.		Examples of use of convection in technology. Solving problems on convection.			
13.		Radiation and absorption.			
14.		Examples of manifestation of radiation and absorption in nature and technology. Solving problems.			
15.		Peculiarities of thermal expansion of water.			

Detailed Plan of Lessons of the Chapter

Lesson No. 1

I. Topic : Introduction to theory of thermal phenomena.

II. Aim: To clarify to pupils the importance of thermal phenomena in nature and technology.

III. Presentation of the new material :

1. Thermal phenomena in nature.
   (*a*) Warming and cooling of air and soil
   (*b*) Melting of ice by the sun.
   (*c*) Winds.

2. Thermal phenomena in technology.
   (*a*) Melting of ores.
   (*b*) Heating of water.
   (*c*) Boiling of water.
3. Use of thermal phenomena in everyday life.
4. Use of thermal phenomena in technology.
5. Revision of the basic concepts of molecular kinetic theory of structure of substances.

Lesson No. 2

I. Topic : Fundamental of the molecular kinetic theory of substances.

II. Aim : To review with pupils the basic concepts of the molecular kinetic theory of substances.

III. Presentation of new material :

1. All bodies consist of molecules. Demonstration of divisibility of the substance.
2. Size of molecules.
3. In all bodies molecules are in constant motion. Demonstration of diffusion of gases and liquids.
4. Between molecules there are empty spaces separating them (Demonstration).
5. Interaction between the molecules.
   (*a*) Mutual attraction (Demonstration).
   (*b*) Mutual repulsion (Demonstration).

IV. Home task.

Lesson No. 3

I. **Topic** : Expansion of solids

II. **Aim** : To explain to pupils change in the sizes of solids on heating and cooling.

III. Question to pupils on:

Revision of the basic concepts of the molecular kinetic theory of substances.

IV. Presentation of new material.

1. Discussion of examples on expansion of solids from everyday observations by pupils.
2. Demonstration of lengthening of wire on heating.
3. Demonstration of expansion of a metal ball on heating and contraction of it on cooling.
4. Different extents of expansion of different metals.

V. Retention :

Solving qualitative problems on expansion of solids.

VI. Home task.

Lesson No. 4

I. **Topic** : Expansion of liquids and gases on heating.

II. **Aim** : To clarify to pupils expansion of liquids and gases on heating.

III. Questions to pupils on :

1. Basic concepts of the molecular kinetic theory.
2. Solving qualitative problems on expansion and contraction of solids on heating and cooling.

IV. Presentation of new material :

1. Discussion of examples on expansion of liquids and gases on heating.
2. Demonstration of expansion of liquids on heating.
3. Demonstration of expansion of air in flask.

V. Retention :

Solving qualitative problems of expansion and contraction of liquids and gases on heating and cooling.

VI. Home task.

Lesson No. 5

I. **Topic** : Concept of temperature and method of measuring it.

II. **Aim** : To clarify to pupils the principle of measuring temperature.

III. Questions to pupils on:

1. Basic concepts of the molecular kinetic theory of substances.
2. Expansion of bodies on heating.
3. Solving qualitative problems on expansion.

IV. Presentation of new material :
1. Subjective determination of the temperature of substances.
2. Objective methods of measuring temperature.
3. Experiment with a flask-model of the thermometer.
4. Dependence of temperature on the speed of molecular motion.

V. Home task.

Lesson No. 6

I. Topic : Principles of construction of a laboratory thermometer.
II. Aim : To clarify to pupils the construction, graduation and the precautions while measuring temperature by the thermometer.
III. Presentation of the new material:
1. Construction of the laboratory thermometer.
2. Fixed points of the Celsius thermometer.
3. Graduation of the thermometer. Demonstration.
4. The precaution taken while measuring temperature by the thermometer.

IV. Retention:
1. Construction of the thermometer.
2. Two main points on the Celsius thermometer.
3. The precaution taken while measuring temperature with the thermometer.

V. Home task.

Lesson No. 7

I. Topic : Construction and application of the clinical, maximum and minimum thermometers.
II. Aim : To clarify the construction and application of different types of thermometers.
III. Questions to pupils as :
1. Solving problems on expansion and contraction of bodies on heating and cooling.
2. Construction of the Celsius thermometer.
3. The precautions in the reading of temperature with a thermometer.

IV. Presentation of new material:
1. Construction and application of the clinical thermometer.
2. Construction of the maximum thermometer.
3. Construction of the minimum thermometer.

V. Home task.

Lesson No. 8

I. Topic : Applications of thermal expansion in technology.

II. Aim: To clarify to pupils the working principle of important technical applications based on thermal expansion of bodies.

III. Presentation of new material:

1. Contact thermometer (Demonstration).
2. Experiment on bimetallic plate (Demonstration).
3. Thermal relay of a bimetallic plate (Demonstration).

IV. Retention :

Solving problems on expansion and contraction of bodies on heating and cooling.

V. Home task.

Lesson No. 9

I. Topic : Transfer of heat by means of heat conduction.

II. Aim : To clarify to pupils the mechanism of the heat transfer by conduction.

III. Presentation of new material :

Discussion of examples from technology and everyday life and nature to illustrate the existence of the process of heat transfer.

IV. Retention :

Solving problems on heat transfer by means of heat conduction.

V. Home task.

Lesson No. 10

I. Topic : Convection.

II. Aim : To clarify to pupils the mechanism of heat transfer by means of convection.

III. Presentation of new material :

1. Demonstration of convection in liquids.
2. Demonstration of convection in gases (in air).
3. Demonstration of rising currents in liquids.
4. Demonstration of rising convectional currents in gases.

IV. Retention :

Solving problems on convection.

V. Home task.

Lesson No. 11

I. **Topic** : Use of convection in technology.

II. **Aim** : To teach pupils skills in solving qualitative and experimental problems on convection.

III. Presentation of new material :

1. The mechanism of heat transfer by means of convection.
2. Use of convection in technology.

IV. Retention :

Solving problems on convection.

V. Home task.

Lesson No. 12

I. **Topic** : Radiation and absorption.

II. **Aim** : To clarify to pupils the method of heat transfer by means of thermal rays.

III. Presentation of the new material :

1 Discussion of examples from nature and technology where heat transfer by means of radiation and absorption is manifested.

2. Demonstration of the process of radiation by a heated body.

3. Demonstration of dependence of radiation and absorption capacity of bodies on their colours.

IV. Retention:

Solving qualitative and experimental problems, on the radiation and absorption.

V. Home task.

Lesson No. 13

I. **Topic** : Use in technology of radiation and absorption.

II. **Aim** : To teach pupils skills in solving problems on radiation and absorption.

III. Questions to pupils as :

1. The difference in the mechanism of heat transfer by means of conduction, convection and radiation.

2. Solving problems on heat conduction and convection.

IV. Presentation of the new material:

Examples of manifestation in nature, technology and everyday life of processes of radiation and absorption (Demonstrations).

V. Retention:

Solving problems on radiation and absorption.

VI. Home task.

Lesson No. 14

I. **Topic:** Peculiarities of thermal expansion of water.

II. **Aim** : To clarify to pupils abnormal properties of water as compared to other substances.

III. Questions to pupils as :

1. Expansion and contraction of bodies on heating and cooling.
2. Forms of heat transfer.
3. Solving problems of all forms of heat transfer.

IV. Presentation of the new material:

1. Water in nature and human life.
2. Abnormal expansion of water when it is heated from 0° to 4°C.
3. Demonstration of peculiarities of thermal expansion of water.
4. Manifestation of peculiar thermal expansion of water in nature.

V. Retention :

Solving qualitative problems on abnormal peculiarities of thermal expansion of water.

VI. Home task.

CHAPTER V

Heat and Work

I. The significance of this chapter

Before the study of this chapter 'heat and work' pupils have already formed elementary concepts of work, mechanical energy, thermal expansion and contraction of bodies, when they are heated, temperature and the processes of transfer of heat. All these concepts familiar to them are to be elaborated in this chapter. In this chapter, the basic ideas of internal energy and the quantity of heat are formed. The concept of work is also broadened. It is clarified that a given quantity of heat is equivalent to a definite quantity of work and on this basis, the law of the conservation and transformation of energy during mechanical and thermal processes is elaborated.

This important law of nature is of great importance for broadening pupil's outlook.

This basic law of all modern natural sciences is presented in such a way that pupils understand its role in all the phenomenon which they study.

II. The content of the chapter

1. Bodies are heated when mechanical work is performed or heat transfer takes place.
2. The internal energy of a body and the quantity of heat.
3. Units of heat.
4. The specific heat of a substance.
5. Calculating the amount of heat necessary to heat a body.
6. The energy of fuel : the heat formed when fuel is burnt.
7. The heat radiated by a heater.
8. The relationship between the unit of work and the unit of the quantity of heat.
9. The law of conservation and transformation of energy. The sun is the main source of energy for the earth.

Laboratory Works

1. Comparing the quantity of heat by mixing together water at different temperatures.
2. Finding the heat radiated by a heater.

III. The analysis of some key concepts of the chapter

Before evolving the methodology of study of thermal phenomenon, it is necessary to analyse the content and interpretation of the basic thermodynamic concepts. Here, the main task is the formation of clear concept of the quantity of heat, energy and work and also pointing out their common and specific features.

(A) The concept of the internal energy

The concept of the internal energy is one of the basic concepts in modern thermodynamics. Let us see how the modern physics explains the internal energy.

The energy of a system depending on the speed at which it is moving as a whole in respect of all other bodies (kinetic energy) and on its position in respect of all other bodies (potential energy), is not included in the concept of the internal energy.

The kinetic and potential energy of a body constitute the total mechanical energy of this body (or system of bodies).

The aggregate of all the forms of energy available in the system under consideration, minus the total mechanical energy, is called the *internal energy*.

Every form of energy is a function of the state of a body. Thus, for instance, mechanical energy (kinetic and potential) is a function of the speeds of a system and its coordinates, i.e., external parameters.

Similarly, the internal energy is a function of the temperature and so on, the parameters of the system determining its internal state.

In any state, a body has only one meaning of energy, e.g., energy is the function of the state that can be interpreted only in one way. This immediately follows from the law of the conservation of energy.

A change in the energy does not depend on the process of the body's transition from one state into another. It depends only on the initial and the final state of the body and is always characteristic of all forms of energy. Hence, the methodology of study of the concept of energy is concerned with this basic task: to clarify to the pupils the fact that when a body is acted on, its state changes and consequently, does its energy. The gain and the loss in the energy are connected with the change in the state in such a way that when the body returns to its initial state its energy takes on its initial value. It is in this way that one will regard energy as a function of the state that can be interpreted only in one way.

In the light of the molecular kinetic theory, internal energy is made up of many components. However, for most processes and phenomena we are interested not in the total amount of the body's internal energy but only to the extent of the change in the internal energy when the body moves from one state to another. In thermal phenomenon taking place at temperatures of the medium range (which are treated in the school course), a change in the internal energy of a body is due to the change either in the kinetic or potential or both these energies of the molecules of this body. The other components of the internal energy do not change. Thus if we represent the internal energy of the body in one state as U^1 and the kinetic and potential energies as E_k^1 and E_p^1 respectively, while all the other forms of the energy as E, we shall have the following equations for any two states :

$$U^1 = E_k^1 + E_p^1 + E$$

$$U^{11} = E_k^{11} + E_p^{11} + E$$

Hence, $U = U^{11} - U^1 = (E_k^{11} - E_k^1) + (E_p^{11} - E_p^1) = E_k + E_p$

Consequently while discussing the meaning of internal energy during the study of thermal phenomenon in this course of physics, we can, without making mistakes, the change in the internal energy of a body as the change only in the kinetic and potential energies of the molecules of the body.

B. The concept of the 'quantity of heat'

Even today in some secondary school and higher school textbooks and some times during process of teaching, the terms "heat" and the "quantity of heat" are wrongly associated with the concept of "stored heat" content in the body.

What is the concept of "quantity of heat" in modern physics ? The concept of "quantity of heat" is included in the formula of the first law of thermodynamics. On the body whose properties remain unchanged we say: the state of the body does not change. Conversely, when some property of a body changes, its state undergoes a change. The state of a body can be changed if some work is performed on it. However, the same result can be achieved in a non-mechanical way. Water is heated both when it is intensively stirred up and when we heat it with a gas burner.

The internal energy of a body can undergo a change in only two possible ways, i e., when work is performed or when heat exchange takes place. Work is a macrophysical process of changing energy. During this process a macroscopic displacement of the body takes place under the impact of the force applied to it Like work, heat exchange is a form of energy transfer. However, heat exchange takes place without any macroscopic displacement and is a result of some elementary process occurring in the world of molecules and atoms. Such macro-processes always take place in great numbers in any substance. Heat exchange is a macrophysical form of energy transfer.

Heat exchange essentially is work too, but it is a sum of the great number of 'micro work' processes in respect of individual molecules. Thus when a hot and a cold body are placed in contact, the fast moving molecules of the former body collide with the slowly moving molecules of the latter body. During this process work is performed which results in a decrease in the kinetic energy of the first body's molecules while the kinetic energy of the molecules of the second body increases. Consequently, heat exchange is a concept close to the concept of work.

Quantitatively, the macro-physical process of energy-change is characterised by the amount of work, while those of the micro-physical process of energy change (heat exchange) by the quantity of heat In the most general way, by exchanging energy with surrounding medium or other bodies, the system in question can receive or give out same quantity heat Q. Here, it can perform work W, or work W can be performed on it. The quantity of heat exchange and work are the two forms in which the body's energy may be transferred to the surrounding medium or *vice versa* (the energy of the medium may be transferred to the body). To express the first principle of thermodynamics in the form of an equation, it is necessary to come to an agreement on the choice of the signs for the quantity of heat and work. We shall assume that the quantity of heat is positive when it is transferred to a system while work will be regarded as positive when a body performs it against some external force. Then the first principle of thermodynamics may be represented as follows :

$$Q=du+W,$$

i.e., the quantity of heat supplied to the body, Q, is spent in changing the internal energy, *du*, and on the work, W, performed by the body. It will be seen from this law in mathematical form that the parts played by heat exchange and mechanical work are identical. In accordance with what was stated above, the quantity of heat should be regarded as a quantity similar to that of the work. So, the quantity of heat is a measure of the change in the body's internal energy in the thermal process. Both the amount of work and the quantity of heat are characteristic of the process of energy-change of a body. We also know that the energy of a body does not depend upon the process of change of energy in the body, therefore, the amount of work and quantity of heat are not energies. In teaching thermal phenomenon, it is necessary to show very clearly the distinction between the concept of energy on the one hand and the concepts of amount of work and the quantity of heat on the other.

IV. Methods of presentation of the points of the chapter that are most difficult for pupil's understanding.

To overcome the difficulties arising from the necessity to help pupils to form many complex and abstract concepts of this chapter, it is necessary to use most

widely demonstrational and laboratory experiments, solving qualitative and experimental problems and discussing examples from everyday life, nature and technology. All this will help to avoid a formal and dogmatic approach to the study of the material and prepare pupils for the study of the subsequent chapters.

A. Heating of Bodies

This question was discussed in chapter "Simple thermal phenomenon". The study of the chapter "heat and work" also begins with the discussion of the heating of bodies. But here it is studied more profoundly. Here we must discuss the heating of bodies, taking place not only during heat exchange but also when mechanical work is done against friction and when one body hits another. In order to associate the concepts of quantity of heat and amount of mechanical work, it is necessary to treat the instance when bodies are heated both as a result of heat exchange and performance of mechanical work. Then it is necessary to proceed to the demonstration of experimental heating of bodies by these two methods, namely, heat exchange and mechanical work To avoid distraction of pupils' attention by some outside happenings the demonstrations must be very simple in arrangement and unsophisticated in content. Thus the following demonstrations may be recommended.

1. **Heating due to heat exchange with the help of thermoscope**—A stand is placed on the demonstration table with a thermoscope fixed. Touching the thermoscope by hand, the teacher shows the displacement of the coloured water in the manometer tube. The phenomenon is explained by the fact that air expands when heated. In this case, the body (air) is heated due to its contact with another body having the higher temperature (i.e., through heat exchange).

2. **The heating of a body when mechanical work is done against friction**—The tube of manometer is filled with coloured water. A hollow metallic container with an outlet tube connected to a manometer is fixed on a stand when the container is rubbed with a woollen cloth piece, a change in the level of the liquid in the limbs of the manometer is observed. The effect is accounted for by the expansion of the air in the container, when it is heated as a result of performing mechanical work against friction.

3. **The heating of a body when mechanical work is performed by striking**—Place a small piece of copper on the anvil. Then strike the copper piece quickly with a hammer (8—10 times) and quickly place it on the container of the previous demonstration.

4. **The heating of a body when mechanical work is performed by compressing the air**—Take the device in which compressed air is used for kindling fire (see picture in the textbook) Show that when the air is compressed quickly, it becomes so hot that the other vapours contained inside the cylinder ignite. This experiment proves that air is heated when compressed quickly.

These or similar experiments help the teacher to conclude that bodies can be heated by the following two methods : by heat exchange (when bodies have different temperatures) and on account of mechanical work performed (against friction, or as a result of impact, compression etc.).

In addition to this conclusion the teacher may explain in a simple way common features of heat exchange and mechanical work on the basis of the molecular kinetic theory. Pupils have already learnt that every body (the air, a piece of copper, ether) consists of molecules. The molecules of any body are in constant thermal motion. The heating of bodies due to heat exchange or mechanical work, is caused by the increase in the speed of the thermal motion of the molecules of the given bodies and consequently the rise in the temperature of the body.

B. Internal Energy

The introduction of the concept of the internal energy of a body is possible in two ways. Proceeding from what pupils know about the body's mechanical energy (kinetic and potential) and from what they know about the fundamentals of the molecular kinetic theory, the teacher, as the basis of analogy, can give the definition of internal energy as the energy of the motion of, and the interaction between, the molecules of a body. This is rather a formal way of explanation, because the 7th grade pupils are not completely convinced of the existence of internal energy as the energy depending on the internal state of the body. The another way consists in proving experimentally the existence of a new form of energy which differs from mechanical energy (kinetic or potential), before introducing the concept of internal energy. We prefer the second way in the course of 7th class physics.

The sequence introducing the concept of internal energy should be as follows:

1. The specific features of mechanical energy (kinetic and potential)
2. Experiments showing another form of energy apart from mechanical energy.
3. The definition of internal energy.
4. Work and heat exchange as processes causing a change in the amount of the internal energy of a body.
5. The quantity heat as the measure of changes in the body's internal energy during heat exchange.

Pupils should be reminded of the following on mechanical energy :

The work performed to raise a body causes an increase in its potential energy. However, no internal change takes place in the body except for a change in its position in respect of other bodies. This process is called a pure mechanical process (neglecting the resistance due to air). When work is done to increase the speed of a body along a horizontal plane and if the friction is so small that it can be neglected, there will be an increase in the body's kinetic energy. In this case too, no internal change in the state of the body takes place. It is only the relative speed of

the body that changes. Consequently one may say that in entirely mechanical processes the mechanical work done on a body (neglecting friction and resistance) causes an increase in its mechanical energy (potential and kinetic) without causing any internal change.

Apart from these entirely mechanical processes, examples can be cited when the mechanical work done is not accompanied by change either in the body's potential or kinetic energy. The following examples can be given. The uniform motion of a body along a horizontal surface In this case, the work performed on the body does not increase either the body's potential energy (the body is moving along the same horizontal surface) or its kinetic energy. Consequently, the body's total mechanical energy in this case remains constant. The following conclusion can be drawn. In those cases when work is performed against friction and resistance, a change in the body's internal state invariably takes place, it is heated. After that we should explain that when the body's internal state changes, a change in its energy takes place. Since this change does not occur in the mechanical energy of the body, so it must be a change in the energy of another form which depends on the body's internal state.

To prove the existence of this another form of energy, we shall put the same argument which was used to help the introduction of the concepts of kinetic and potential energy. We have said that a body has a stored energy if it is capable of performing mechanical work, i.e., the concept of the ability of bodies to perform work was associated with the amount of energy. Making use of this definition and the demonstrations used for the formation of the concept of the two forms of mechanical energy, we can prove the existence of this new form of energy with the help of a simple demonstration.

Experiment 1

A test tube made of metal is fixed in a centrifugal machine. Let us pour a little of the ether into the test tube and cork it. Pressing the test tube with the help of special wooden blocks let us set the test tube in rotation By doing so the cork will be thrown out of the test tube (see picture in the textbook). It means that the energy of the ether and its vapour has increased since work is done in throwing out the cork. Let us analyse the cause of this increase in the energy of the ether and its vapour. At a constant speed of rotation of the test tube, the kinetic energy does not change. Again the level of the liquid may also be considered approximately constant, hence there is no change in the potential energy. So the total mechanical energy of the ether and its vapour has not changed. Hence, the change in energy of the ether and its vapour must be due to the change in another form of energy. Before the test tube was set in rotation, the ether vapour could not do this work but after some rotation the ether vapours could perform mechanical work. It means that after rotation the ether vapours possess energy greater than the energy

before rotation Hence, work against friction has not increased the mechanical energy of ether but has increased the energy of another form depending on the internal state. In other words, ether was heated during rotation and the vapours formed performed the work necessary to throw out the cork.

Thus proceeding from experiment 1, it is possible to establish the fact of the existence of energy depending on the body's internal state as well as the ways of increasing the amount of this energy. Experiment 2 also helps to show the existence of the same form of energy.

Experiment 2

Let us pump air into a thick-walled corked glass vessel in which there is a little water (see picture in the textbook). The vessel contains water vapour besides the air. When the pressure of air in the vessel is increased, the cork is thrown out, and simultaneously the vessel is full of mist. The mist is formed from water vapour when its temperature decreases. Pupils are not aware of this process; therefore, it can be explained by reminding them of the well-known phenomenon of formation of dew in nature.

Pupils know that in winter dew is formed on the tree leaves and grass in the morning. The formation of the dew in nature is the same as in this experiment.

Atmospheric air always contains water vapour and when the temperature decreases the vapour turns into the tiny drops of water depositing on various objects. Thus returning to the experiment, attention should be drawn to the following two facts. The mixture of air and water vapour has performed some work to throw out the cork. Consequently this mixture has a certain amount of energy depending on its internal state. On the other hand after the cork had been thrown away, the temperature of the mixture decreased. If the vessel is corked again and air is again pumped into the vessel, the mist will disappear. Consequently as a result of performing work on the mixture of air and water vapour the amount of its energy increased again which led to an increase in the temperature which causes the tiny drops of water again to turn into vapour. As in experiment 1, the amount of total mechanical energy of the mixture of air and water vapour remains constant.

Proceeding from these two experiments the concept of the body's internal energy may be introduced, namely, by the body's internal energy we mean the energy depending on its internal state. Then the teacher may pass over to explaining what internal energy means in the light of the molecular kinetic theory.

From the fundamentals of the molecular kinetic theory pupils know that all bodies consist of molecules which are in constant motion. Like moving body having kinetic energy (mechanical), moving molecule has kinetic energy too. The kinetic energy of one molecule is of course very small but the total kinetic energy of the huge number of molecules of a body is considerable.

As in the case of potential energy (mechanical), which is possessed by different parts of the same body (for instance, a compressed spring), there is interaction between individual molecules in any body. Consequently, the molecules of a body have same potential energy.

Hence in the light of the molecular kinetic theory the internal energy of a body consists basically of the kinetic and potential energies of these molecules Pupils' attention should be drawn to the fact that the amount of the internal energy of a body does not depend on the amount of the mechanical energy of the body as a whole, since the amount of the internal energy of a body at a relative rest and in motion, will be one and the same quantity or in other words, the internal energy of a body does not change in quantity if the body is on the earth's surface or is raised to some height above the earth's surface, i e , it does not depend on the potential energy of the body as a whole (on mechanical potential energy).

Finally, the last point to be discussed is on factors by which the change in the internal energy of a body depends.

Pupils have already learnt that a change in the temperature of the body depends on a change in the speed of the molecules of the body, e.g., a rise in the temperature of the body is caused by the increase in the speed of the molecular motion, while a decrease in the temperature is due to the decrease in the speed of the molecular motion. Hence it follows that with an increase in the temperature of a body its internal energy increases, for the greater the speed of the molecular motion the larger the amount of the kinetic energy possessed by its molecules and, consequently, the larger the amount of internal energy.

Conversely, with a decrease in the temperature, the speed of the molecular motion decreases and consequently there is a decrease in the molecular kinetic energy, e.g., the amount of the internal energy of the body decreases.

Thus to achieve an increase in the internal energy of the body, it is necessary to heat it. On the other hand pupils know that a body can be heated by two methods: by performing work as a body or through heat exchange. Hence it follows that the internal energy of a body can undergo a change by performing work as well as by heat transfer. Now we can give a scientific definition of the quantity of heat.

The change (increase or decrease) in the internal energy of a body during heat exchange is called the quantity of heat.

The remaining topics, namely, the concept of heat units, specific heat, calculation of the quantity of heat, the energy of a fuel, etc., can be easily explained to pupils. However, this can be achieved only by showing demonstrations and systematically solving problems on each of these topics.

Below are the problems of different types.

PROBLEMS ON THE TOPIC

I. Measuring the Quantity of Heat

1. A thermos whose capacity is 3 litres is filled with boiling water. After 24 hours the temperature of the water in the thermos became 70°C. Find the loss of the quantity of heat during that period.

2. What quantity of heat is needed to heat 1 kg of water from 10°C to 11°C ?

3. A brass cylinder whose mass is 15 kg was heated from 15°C to 75°C. What quantity of heat was needed ?

4. What quantity of heat is released by cooling a hot brick stove of mass of 350 kg by 40°C ?

5. What quantity of heat is needed to increase the temperature of water in a swimming pool from 13°C to 25°C ? The length of the pool is 100 metres, width 6 metres and the depth 2 metres.

6. What quantity of heat is needed to increase the temperature of a copper block from 20°C to 100°C (the size of the block is $10 \times 5 \times 2$ cm) ?

7. What amount of heat is needed to warm up the air in a room of 60 cubic metres from 10°C to 20°C ?

8. 50 g of water at 80°C was poured into a vessel containing 150 g of water at 60°C. Find the temperature of the mixture ?

9. How many calories are equivalent to 2135 kg wt m ?

10. How many kg wt m are equivalent to 6 kilo calories ?

11. How many calories are equivalent to one kg wt m of work ?

12. Express 10 kilo calories as joules.

13. A steel drill of 100 g was heated from 15°C to 150°C while doing work. What amount of mechanical work done by the motor was used up to heat the drill ?

II. Heat of combustion of the fuel

Thermal Efficiency

1. 2700 kilo calories were released when 3 kg of gun powder was burnt. Find the heat of combustion of the powder.

2. How many kilo calories are released when 15 kg of charcoal are burnt ?

3. What would be the difference between the quantities of heat released by burning 2 kg of petrol and 2 kg of dry fire-wood ?

4. How much diesel oil is required to be burnt to release 42,000 kilo calories ?

5. By how many degrees will 100 litres of water be heated by burning 0.5 kg of charcoal assuming that all the heat goes to heat the water ?

6. Find the thermal efficiency of the boiler if for heating 6 litres of water from 25°C to 100°C, 0.12 kg of charcoal is needed.

7. What is the thermal efficiency of a primus stove if 40 ml of kerosene were needed to heat 2 litres of water from 12°C to boiling point (100°C) ?

8. 43.1 kilograms of coal were burnt in a melting furnace to heat 300 kilograms of copper from 13°C to 1083°C. Find the thermal efficiency of the furnace.

9. What amount of water will be heated to its boiling point by burning 0.5 kg of wood whose heat of combustion is 3000 kilo calories per kilogram if the thermal efficiency of the boiler is 30% ? The initial temperature of the water is 20°C.

10. The tank of a primus stove, whose thermal efficiency is 40 per cent, contains 625 ml of kerosene. What amount of water can be heated to boiling if all the kerosene is burnt ? The initial temperature of the water is 20°C.

THE TOPICAL PLAN

No. of Lesson	Date of Lesson	Topic of Lesson	Method of work	Demonstration	Home work
1	2	3	4	5	6
1.		Bodies are heated when mechanical work is performed.			
2.		Similarity of heat exchange and mechanical work.			
3.		Peculiarities of the body's mechanical energy (kinetic and potential) neglecting friction and resistance.			
4.		Substantiation of the existence of a form of energy other than mechanical energy.			
5.		The internal energy of the body.			
6.		Work and heat exchange as processes causing changes in the body's internal energy.			
7.		Quantity of heat as a measure of the change in the body's internal energy during heat exchange.			
8.		Specific heat of the substance.			
9.		Calculation of the amount of heat required for heating.			
10.		Solving problems on calculation of the amount of heat.			

1	2	3	4	5	6
11.		Laboratory work comparing the quantities of heat (lost and gained) by hot and cold water.			
12.		Solving problems on specific heat.			
13.		Heat of combustion of fuel.			
14.		Thermal efficiency of the heater.			
15.		Solving problems on thermal efficiency of the heater.			
16.		Laboratory work. Finding the thermal efficiency of a spirit burner.			
17.		Relationship between units of work, and the quantity of heat.			
18.		Solving problems.			
19.		The law of transformation and conservation of energy. The sun is the main source of energy on the earth.			
20.		Revision of the whole chapter.			
21.		Written test on the chapter.			

The Detailed Plans of the Lessons

Lesson No. 1

Topic : Bodies are heated when mechanical work is performed.

Aim : To clarify to pupils that the heating of bodies can be obtained by doing mechanical work on the body.

Plan of presentation of the new material:

1. Introduction :

The importance and significance for technology in everyday life of this sub-topic.

2. The heating of bodies during heat exchange.

3. The heating of bodies when mechanical work is performed against friction (demonstration).

4. The heating of bodies by impact (demonstration).

5. Retention.

(*a*) During which processes is it possible to heat bodies?

(*b*) Give examples of the heating of bodies when mechanical work is performed against friction.

(*c*) Give examples of the heating of bodies when work is performed due to impact.

6. Home task.

Lesson No. 2

Topic : The similarity of heat exchange and mechanical work.

Aim : To show that the process of heating can be achieved through two processes.

I. *Questions to Pupils* :

(*a*) By what means can bodies be heated ?

(*b*) Give instances of the heating of bodies when work is performed against friction.

(*c*) Give instances of the heating of bodies due to impact.

(*d*) Give the basic points of the molecular kinetic theory.

II. *Presentation of the new material* :

(*a*) The heating of bodies when work is performed to compress the air (demonstration).

(*b*) The heating of ether by heat exchange and mechanical work performed against friction (demonstration).

III. *Home task.*

Lesson No. 3

Topic : Pure mechanical processes.

Aim : To clarify to pupils that purely mechanical energy does not influence the internal state of a body.

I. *Questions to Pupils* :

1. What determines the thermal state of a body ?
2. What do you mean by the energy of a body ?
3. What two forms of mechanical energy you know ?
4. What is the similarity between heat exchange and mechanical work ?
5. In what cases are bodies heated when mechanical work is performed ?

II. *Presentation of the new material* :

1. A body has energy if it is capable of performing mechanical work.

2 The work done to raise a body to some height is spent in giving to it some amount of potential energy. During this process, no internal change takes place in the body (neglecting the forces of friction).

3. The work performed to speed up a body along a horizontal surface is spent in giving to it some amount of kinetic energy without any internal change in the body neglecting the force of friction.

4. In purely mechanical process the work performed on a body leads to an increase in the mechanical energy (potential and kinetic) without causing any internal change.

5. By the internal state of a body we mean the parameters characteristic of the internal state, for instance, the temperature of the body.

III. *Retention* :

1. What processes are called purely mechanical?

2. On what is the work performed on a body spent, if resistance and friction are negligible ?

3. What happens to the amount of mechanical energy if the body performs mechanical work (in purely mechanical processes).

4. What happens to the amount of the mechanical energy of a body if work is performed on it.

IV. *Home Task.*

Lesson No. 4

Topic : Substantiation of the existence of a form of energy other than mechanical energy.

Aim : To clarify to pupils that work performed on a body does not always lead to an increase in mechanical energy.

I. *Questions to pupils* :

1. When does a body possess energy ?
2. What two forms of mechanical energy do you know ?
3. What processes are called purely mechanical ?
4. On what is spent the work performed on a body (neglecting friction and resistance) ?
5. How is it possible to find out that body possesses mechanical energy ?
6. What are the basic points of the molecular kinetic theory ?

II. *Presentation of the new material* :

1. Analysis of the examples when work performed is not accompanied by a change in the potential or kinetic energy of the body (uniform motion of the block along a horizontal surface, uniform motion of the cutter of a lathe machine, etc.).

2. The work performed on a body against friction, or resistance is always accompanied by a change in the internal state of the body by heating it.

3. Changes in the internal state of the body are associated with changes in the amount of energy that depends on the internal state.

4. Recognition of energy other than mechanical energy :

(*a*) Demonstration of the heating of metal test tube on account of work done against friction.

(*b*) Demonstration of the throwing out of the cork from the vessel filled with a little water when air is pumped into it.

(*c*) Ignition of ether when the air is heated by compressing the cylinder.

5. Conclusions from all these demonstrations.

III. *Home Task.*

Lesson No. 5

Topic : Internal energy.

Aim : To clarify to pupils the concept of internal energy.

I. *Questions to pupils* :

1. In which cases the work perfoimed on a body do not lead to an increase in the mechanical energy ?

2 What happens with the body's internal state when mechanical work is performed against friction and resistance ?

3. Explain the experiment with the metal test tube containing some ether.

4. Explain the experiment of pumping the air into a large vessel containing some water.

5. Explain the experiment of heating the air by compressing it in a cylinder.

II. *Presentation of new material* :

1. Internal energy is the energy which depends on the internal state of the body.

2. Explanation of the molecular kinetic idea of internal energy.

(*a*) Molecules possess kinetic energy because they are in constant motion.

(*b*) Molecules possess potential energy because there is interaction between them.

(*c*) Basically the body's internal energy consists of kinetic and potential energy of the body's molecules.

3. The amount of the body's internal energy does not depend on the body's mechanical energy.

III. *Home Task.*

Lesson No. 6

Topic : Work and heat exchange as processes causing a change in internal energy.

Aim : To clarify to pupils that a change in the amount of the body's internal energy can be achieved through two processes : work or heat exchange.

I. *Questions to pupils* :

1. Basic points of the molecular kinetic theory.

2. What does the temperature of a body depend on ?

3. In which two forms does mechanical energy exist.

4. Through which two processing is it possible to heat bodies ?

5. In which cases, does the work performed on a body cause the heating of the body.

6. In which cases, does the work performed not cause the heating of the body.

7. What units of mechanical work do you know ?

II. *Presentation of new material* :

1. The speed of the process of diffusion depends on the temperature. The higher the temperature the faster the process of diffusion,

2. When a body is heated the speed of the molecular motion increases. On the other hand, when the body is cooled the speed of the molecular motion decreases.

3. The amount of the body's kinetic energy depends on its mass and speed.

4. The amount of the molecular kinetic energy of the same body depends only on the speed of its molecules.

5. The amount of the body's internal energy can be changed by changing its temperature.

6. Increase in the amount of internal energy of a body by increasing the temperature of the body is achieved—

(*a*) by performing mechanical work on the body,

(*b*) by heat exchange.

7. Decrease in the amount of internal energy of a body by decreasing the temperature of the body is achieved—

(*a*) by letting the body perform same work.

(*b*) by heat exchange.

III. *Retention* :

Solving qualitative problems on internal energy of the body.

IV. *Home Task* :

Lesson No. 7

Topic : The quantity of heat as a measure of the change in the internal energy of the body during heat exchange.

Aim : To explain to pupils the concept of the quantity of heat.

I. *Questions to pupils* :

1. What is the internal energy of a body ?

2. In what way does the internal energy of the body depend on its temperature ?

3. What happens to the temperature of the body if it performs work at the expense of its internal energy ?

4. Why does the internal energy of the body increase when the body is heated ?

5. What formula do we use to calculate the amount of mechanical work?

6. What different units of mechanical work do you know ?

II. *Presentation of new material* :

1. Dependence of the quantity of heat on the mass of the heated body.

2. Dependence of the quantity of heat on the difference of the initial and final temperatures of the heated body.

3. The unit of the quantity of heat.

4. The formula for the calculation of the quantity of heat required to heat some water :

$$m(t_2^o - t_1^o)$$

III. *Retention* :

Solving problems of calculating the quantity of heat required to heat some water.

IV. *Home Task.*

Lesson No. 8

Topic : Specific heat of substance.

Aim : To explain to pupils the physical meaning of the specific heat of a substance.

I. *Questions to pupils* :

1. On what quantities does the amount of heat required for heating some water depend ?
2. What units of the quantity of heat do you know ?
3. What is 1 calorie ?
4. What is 1 kilo calories ?
5. By what formula is it possible to calculate the quantity of heat required to heat some water ?

$$q = m(t_2^o - t_1^o)$$

6. By what formula is it possible to calculate the quantity of heat released by some water ?

$$q = m(t_1^o - t_2^o)$$

II. *Presentation of new material*:

1. Is it possible to calculate the quantity of heat required to heat some substance with the help of the formula $q = m(t_2^o - t_1^o)$
2. Demonstration of heating equal amounts of different liquids which have the same initial temperature.
3. To heat equal amounts of different substances by the same rise in temperature, different quantities of heat are required.
4. Introducing the concept of specific heat of a substance.
5. The double meaning of the concepts of specific heat of a substance :

(*a*) The quantity of heat required to heat 1 g of substance by 1 degree Celsius.

(*b*) The quantity of heat released by 1 g of substance when it cools by 1 C.

6. The units in which the specific heat is measured.
7. Table of specific heat of different substances,

III. *Home Task*.

Lesson No. 9

Topic : Calculation of the quantity of heat.
Aim : To teach pupils skills for calculating the quantity of heat needed for heating.
I. *Questions to pupils* :

1. What is the specific heat of a substance ?
2. What does the specific heat of a substance show ?
3. In what units, is the specific heat of a substance measured ?
4. What formula is used to calculate the quantity of heat needed to heat some water ?
5. What is the specific heat of water ?
6. What formula is used to calculate the quantity of heat released by a given amount of hot water ?

II. *Presentation of new material*:

1. Use of the arithmetic methods in concrete problems to calculate the amounts of heat received by a body when it is heated. *Example*: Calculate the quantity of heat needed for heating 200 g of aluminium from 10 degree to 40 degree Celsius.

2. Deriving the formula for the calculation of the quantity of heat needed to heat a body.

$$q = sm(t_2^o - t_1^o)$$

3. Deriving the formula for the calculation of the quantity of heat released by body.

$$q = sm(t_1^o - t_2^o)$$

III. *Retention* :

Solving problems on calculating the quantity of heat.

IV. *Home Task.*

Lesson No. 10

Topic : Solving problems on calculating the quantity of heat.
Aim : To develop skills in solving problems.
I. *Questions to pupils* ;

1. What does the specific heat of a substance indicate ?
2. In what units is the specific heat of a substance measured ?
3. The formula for calculating the quantity of heat needed for heating the body.
4. The formula for calculating the quantity of heat released by a body.
5. What does the expression $t_2^o - t_1^o$, indicate.

II. *Retention* :

Solving experimental problems:—(i) Demonstration of the Tyndal apparatus.
(ii) Solving qualitative and quantitative problems.

III. *Home Task.*

Lesson No. 11

Topic : Laboratory work : Comparing the quantity of heat by mixing hot and cold water.

Aim : Acquiring skills by pupils in simple caloriemetric measurements.

I. *Introductory Talk*:

In this five to seven minutes brief talk, the teacher should explain the following points :—

(*i*) The topic of the laboratory work.

(*ii*) The aim of the laboratory work.

(*iii*) The content of the experimental task.

(*iv*) The requisite equipments.

One laboratory set of equipments is on the demonstration table of the teacher.

(*a*) Calorimeter.

(*b*) Cylindrical measuring glass.

(*c*) Thermometer.

(*d*) Jar with cold water.

(*e*) A jar with hot water.

(*v*) Explanation of the techniques of measuring the temperature.

(*vi*) The tabular form for recording results of the measurement (see textbook).

(*vii*) Organising the work between groups of two or three students.

After the teacher's explanations, pupils write down the name of the laboratory work and the table for recording the results in a special note-book.

Meanwhile pupils on duty distribute the sets of equipments arranged beforehand on each of the table. After that pupils start work while the teacher supervises the work of the individuals of a group, helping pupils if they face difficulties. Three minutes before the end of the lesson, the measurement should be finished, the apparatus collected, and the note-book for laboratory work handed over to the teacher.

Lesson No. 12

Topic : Solving problems on the specific heat of a substance.

Aim : To acquire skills in solving problems of this type.

1. What units of heat do you know ?
2. What is the calorie ?
3. What is the kilo calorie ?
4. What is the specific heat of a substance ?
5. In what units is the specific heat of a substance measured ?
6. What formula is used to calculate the quantity of heat needed to heat a body ?
7. What formula is used to calculate the quantity of heat released by a body when it cools ?

8. If in a problem the mass of the heated body is given in Kg, in what units should one take the specific heat of the substance ?

9. If in a problem, the mass of the heated body is given in grams, in what units must one take the specific heat of a substance ?

10. Why does the numerical value for specific heat of the substance not change when it is represented in different units ? Thus, for instance, the specific heat of water is :

$$S = \frac{1 \text{ Cal} \qquad 0.09 \text{ kilocal}}{1\text{g degree c}}$$

$$S = 0.09 \frac{\text{Cal}}{\text{g degree C}} = 0.09 \frac{\text{Kilocal}}{\text{Kg degree C}}$$

II. *Retention* :

Solving problems : For this lesson, the teacher should select problems of different types (calculation, qualitative and experimental problems) to be solved in this lesson (see the problems suggested in this guide).

III. *Home Task* :

The problems given in the textbook should be assigned to pupils.

Note.—Clear understanding of the given formula by pupils is very important. Therefore, solving problems with the help of formula should follow the arithmetic method.

While solving problems (by using the formula) on the board one should stick to writing down the conditions given, the formula to be used and the solution in a brief form as indicated in the textbook.

Lesson No. 13

Topic : The heat of combustion of fuel.

Aim : To explain the concepts of the heat of combustion to the pupils.

I. *Questions to pupils :*

Different types of problems for calculating the quantity of heat during heating.

II. *Presentation of new material :*

1. Different types of fuel;
2. Release of the quantity of heat when fuel is burnt;
3. Elementary ideas of the chemistry of fuel combustion;
4. Heat of combustion of a fuel;
5. Familiarisation with the table of heat of combustion of different fuels;
6. Units in which the heat of combustion of a fuel is measured;
7. The total quantity of the heat released when fuel is burnt;

$$q = Qm$$

III. *Retention :*

Solving problems on calculation of the amount of heat released when fuel

burns completely.

IV *Home Task.*

Lesson No. 14

Topic : Thermal efficiency of a heater.

Aim : To explain the concept of thermal efficiency of a heater to the pupils.

I. *Questions to pupils :*

1. What is the heat of combustion of a fuel ?
2. In what units is the heat released by burning a fuel measured ?
3. What formula is used to calculate the heat released by a fuel when it burns up completely ?
4. Solving problems by using the formula $q=Qm$.

II. *Presentation of new material :*

1. Examination of the process of heating water in a vessel by spirit lamp.
2. The concept of useful heat.
3. The concept of the total heat released by burning fuel.
4. The concept of the thermal efficiency of the heater.

$$\eta = \frac{q_u}{q_t} \times 100\%$$

III. *Home Task.*

Lesson No. 15

Topic : Solving problems on thermal efficiency of the heater.

Aim : To teach pupils skills in solving problems of this type.

I. *Questions to pupils :*

1. What is the useful quantity of heat ?
2. How is the useful quantity of heat calculated ?
3. What is the total quantity of heat ?
4. How is the total quantity of heat released by burning a fuel calculated ?
5. Why is the total quantity of heat always bigger than useful quantity in any type of heater ?
6. Why does any type of thermal apparatus produce useful heat less than 100 per cent ?
7. In what units is the heat radiation of a heater measured ?

II. *Retention* :

The calculation of thermal efficiency (Refer to Problem 8 given in this chapter).

$m = 43.1$ kg of coal

$m = 300$ kg of copper

$t_1^o = 13°C$

$t_2^o = 1083°C$

$S = 0.09 \frac{\text{kilocal.}}{\text{kg degree C}}$

$q_u = sm\,(t_2^\circ - t_1^\circ)$

$= 0.09 \frac{\textit{kilocal.} \times 300 \text{ kgx}}{\text{kg degree C}}$

$(1083° - 13°)C = 28{,}890$ kilocal.

$= 8000 \quad 43.1 \text{ kg} \quad 344{,}800$ kilocal.

$n = s.\,m.\,(t_2^\circ - t_1^\circ)$

$= \frac{28{,}890 \times 100}{344{,}800}$ per cent

$= 8.4$ per cent.

III. *Home Task.*

Lesson No. 16

Topic : Laboratory work : The calculation of the thermal efficiency of the spirit lamp.

Aim : To train pupils to acquire skills in calorimetric measurement.

I. *Introductory Talk* :

1. Name of the laboratory work.
2. Aim of the laboratory work.
3. Requisite equipments.
4. Measurement procedure (with demonstration of the set of the apparatus).
5. The methods of measurement (see the description of the work in the text-book).
6. The table in which the measurement should be written.
7. Distribution of the pre-arranged sets of the devices to the different groups of pupils.

II. *Performance of the work by pupils.*

III. *Collection of pupils' laboratory work note-books.*

IV. *Home Task.*

Lesson No. 17

Topic : Relation between the units of the work and the units of quantity of heat.

Aim : To explain to pupil the equivalence between the amount of mechanical work and quantity of heat.

I. *Evaluation :*

1. What is the internal energy of a body?

2. What is the similarity in the concepts of mechanical work and heat exchange ?

3. What are the processes through which a body can be heated?

4. In what units is the quantity of heat measured?

5. In what units is the mechanical work measured?

II. *Presentation of new material :*

1. What is the similarity between the mechanical work and the heat exchange (repetition of the demonstration of heating ether in test tube and the amount of the mechanical work performed).

2. The idea of the Joule experiment in finding the correlations between the mechanical work performed to increase the internal energy of the body by the same amount as in heat exchange.

3. When mechanical work of 427 kg wt m is performed on a body, the body may be heated to the same degree as in transferring one kilocalorie of heat in the process of heat exchange, *i e.*, 427 kg wt m work is equivalent to 1 kilocalorie of heat.

4. When mechanical work of 427 kg wt m is performed on a body, the internal energy of the body increases by 1 kilocalorie or 4190 joules.

III. *Retention :* Solving problems.

IV. *Home Task.*

Lesson No. 18

Topic : Solving problems on correlation between the units of mechanical work and the units of quantity of heat.

Aim : To teach pupils skills in solving problems of this type.

I. *Evaluation :*

1. How is it possible to change the internal energy of a body ?

2. What is common between mechanical work and the quantity of heat?

3. What units of mechanical work do you know?

4. What units of the quantity of heat do you know ?

5. What is the correlation between the kg wt m and kilocalorie?

6. What is the correlation between the joules and the kilocalorie ?

II. *Retention :*

Solving problems of correlations between the units of mechanical work and the quantity of heat.

III. *Home Task.*

Lesson No. 19

Topic : Law of conservation and transformation of energy in mechanical and thermal processes.

Aim : To widen pupils' ideas of the importance of the law of the conservation and transformation of energy.

I. *Presentation of the new material :*

1. Demonstration of Maxwell's pendulum.
2. Formulation of the law of the conservation and transformation of energy for purely mechanical processes.
3. Observing by experimenting with the Maxwell's pendulum that there is a decrease in the magnitude of the total mechanical energy of the pendulum.
4. What causes the increase in the total mechanical energy of the Maxwell's pendulum.
5. Consideration of examples when transfer of mechanical energy of the body into its internal energy is observed.
6. Formulation of the law in the most general form.
7. Consideration of the energy transformation on the earth caused by the action of the sun.

II. *Home Task.*

Lesson No. 20

Topic : Revision of the entire topic.

Aim : To prepare pupils for the test.

I. *Plan of revision of the teaching material :*

1. Methods of heating bodies.
2. Common features of heat exchange and mechanical work.
3. Units of measurement of mechanical work and the quantity of heat.
4. Formula for calculation of mechanical work.
5. Formula for calculation of the quantity of heat required to heat a body or released when a body cools.
6. What is the specific heat of a substance ?
7. The correlation between the units of work and the units of quantity of heat.
8. Heat of combustion of fuel.
9. Formula for calculation of the quantity of heat released in complete burning of a fuel.
10. Thermal efficiency of a heater and the formula to calculate it.
11. The law of conservation and transformation of energy.

II. *Retention :*

Solving problems of different types.

III. *Home Task :*

To prepare for the test.

Lesson No. 21

Topic : Test.

Aim : To check how pupils have assimilated the basic concepts of the topic.

For this lesson, the teacher should make up four variants of the test which should be of the same degree. Each variant should include three problems:

1. To calculate the amount of heat required to heat a body (the amount of heat released when the body cools).

2. The correlation between the units of mechanical work and the units of the quantity of heat.

3. On the concept of internal energy.

CHAPTER VI

Transition of Substance from One Aggregate State into Another

I. *Significance of the chapter* :

This chapter winds up the study of thermal processes in the course of physics for Class VII.

In this chapter further development of the important concept of the body's internal energy takes place, the idea of the molecular kinetic theory is enlarged as well as the law of the conservation and transformation of energy are studied. While studying the transition of substance from one aggregate state into another students develop a graphic idea of the transformations and interrelation of natural phenomena.

The material of the chapter is of great polytechnical significance: it prepares pupils for understanding the important technological processes such as melting and crystallization of metals, preparation of various modern alloys and their technological applications, production of high temperature steam and its application in technology, etc.

Important technological applications

II. *The contents of the chapter*:

1. Crystalline and amorphous bodies.
2. Melting and crystallization of crystalline substances.
3. Heat of fusion and crystallization.
4. Alloys and their applications.
5. Evaporation
6. Boiling. The heat of vaporization and condensation.
7. Dependence of boiling point on external pressure,

Laboratory work

1. Observation of heating and melting of naphthalene.
2. Observation of heating and boiling of water.

III. *Methodological analysis of some points of the chapter*

Analysing this chapter we confine ourselves to the methodological analysis alone because basic concepts are introduced in this chapter. Here only further development of the already introduced concepts and laws takes place.

1. In the introductory talk an elementary idea is given on the structure of the two types of solid bodies : Crystalline and amorphous. Attention is mostly focussed on crystalline substances which will be further studied. During this talk students should have on their tables samples of two types of substances. These can be small pieces of crystalline substances (salt, pig iron, mica) and amorphous bodies (rasin, wax, plasticine).

If magnifying glasses are available in the school these should be distributed among pupils for observing these samples.

2. *The process of melting of crystalline substances*

Discussion of the process of melting and its regularities is based on the experiment of melting naphthalene. Observation of the melting process is accompanied by drawing the graph of melting temperature against time. The experiment shows that first the crystalline naphthalene is heated without undergoing any change in its aggregate state.

When a certain temperature is reached, further increase in the temperature discontinues in spite of the continuation of the energy inflow to the naphthalene from the spirit lamp. After the entire crystalline body has melted, a further increase is observed in the temperature of the liquid obtained from the solid substance.

In this demonstration the liquid naphthalene should be heated to the temperature of about 95°C.

On the basis of this demonstration the teacher can introduce the concept of the melting point and draw pupils' attention to the following characteristics of the melting process.

1. Crystalline substances melt only at certain temperatures (at constant external pressure).

2. Temperature remains constant during the entire process of melting

Attention should be drawn to the fact that during the process of melting the mass of the crystalline napthalene gradually decreases whereas the mass of the liquid naphthalene increases.

After discussing this experiment the teacher should explain the observed characteristics of the melting process. This experimental graph consists of three sections : AB—heating crystalline naphthalene ; BC—melting of naphthalene; CD—heating of liquid naphthalene.

The teacher puts the following question to his pupils. Where does the energy released during the burning of spirit in the spirit lamp go at the section of the graph AB ? This energy is spent in heating crystalline naphthalene from its initial temperature (classroom temperature), to the melting point of naphthalene. What happens to the internal energy of the crystalline body in the section of the graph AB ? This is the next question.

The internal energy of crystalline naphthalene increases. The teacher should ask these On what account does the internal energy of crystalline naphthalene increase in the section AB ?

Pupils should be reminded that the body's internal energy consists in mainly of the kinetic and potential energies of the molecules of the given body. Since in the section AB the temperature of naphthalene rises, consequently the average speed of the thermal motion of molecules increases leading to the increase in the energy of the molecules Thus the increase in the internal energy of crystalline naphthalene in the section AB takes place on account of the increase in the kinetic energy of its molecules.

After this the fourth question can be put as: To what extent has the internal energy of crystalline naphthalene increased in the section AB ?

Pupils already know that the quantity of heat required to heat a body is calculated by the following formula :

$Q = s \times m\,(t^{\circ}_{2} - t^{\circ}_{1})$

Consequently, we may say that the internal energy of crystalline naphthalene increases by q_1 calories.

Now the teacher should take up the analysis of the second section BC of the graph which is very difficult for the pupils.

The first question to pupils will be : In spite of the heat supplied by spirit lamp why temperature of naphthalene in this state (corresponding to the section BC) does not increase ?

To help pupils to give the correct answer they should be told that in the section BC the mass of crystalline naphthalene decreased with time whereas the mass of liquid naphthalene increases.

The temperature in this section BC remains constant because the energy obtained from the spirit lamp does not increase the speed of the molecular motion and consequently there is no increase in the kinetic energy of the naphthalene molecules.

Question No. 2 : Where does the energy released due to the burning of spirit in the section BC of the graph go ?

This energy is spent in the breaking of the crystalline lattice of naphthalene the process of melting crystalline (to overcome the alternative forces between the molecules in the crystalline state).

Thus the process of melting a crystalline substance is accompanied by absorption of the energy released during the burning of spirit in the spirit lamp. During

this process the temperature of the melting substance does not increase, consequently the energy absorbed by the substance is not spent in increasing the kinetic energy of the molecules.

Hence it follows that the energy which is being absorbed is spent in increasing the potential energy of the molecules. In fact during the process of melting the forces of molecular attraction diminish, the distances between molecules increase too, and consequently the potential energy of the molecules increases. Now we may draw the following conclusions. Bodies with a crystalline structure on reaching the melting temperature begin to melt if an inflow of energy takes place. This energy is spent in increasing the internal energy of the melting body on account of the increase in the potential energy of its molecules.

The following question seems very natural after these considerations. In what way is it possible to calculate the quantity of heat required for melting a crystalline body at its melting temperature? For this purpose the teacher introduces the concept of heat of fusion of a crystal as the quantity of heat required for the transformation of one gram of a crystalline substance, at its melting point, into liquid without any change of temperature. It is possible to say as far as energy is concerned that the heat of fusion of a substance shows to what extent the internal energy of one gram of liquid substance exceeds the internal energy of one gram of the same substance in the crystalline state provided the temperature remains constant *i.e.* equal to its melting point. For instance, heat of fusion of ice is 80 cal/g. This means that one gram of ice at 0°C has less internal energy than one gram of water at same temperature and this difference of energy is equal to 80 calories. Heat of fusion can be measured in calorie per gram or kilo calorie per kilogram *i.e.* cal/g or $\frac{kilocal}{kg}$.

By using inductive method it is easy to provide pupils with the formula for calculation of the quantity of heat required for melting any crystalline substance at its melting point.

Suppose it is necessary to melt a piece of ice of mass, m gram at the melting point, *i.e.,* 0°C. How the required quantity of heat can be calculated?

In the table available in the textbook the pupils find that the heat of fusion of ice is 80 cal/g.

This means that to melt one gram of ice at 0°C it should receive 80 calories of heat. To melt 2 grams of ice we need 80 calories $\times$ 2, to melt 3 grams of ice 80 calories $\times$ 3 and finally to melt a piece of ice with a mass of m, we need $80 \times m$ cal.

Hence we obtain that $q = l \times m$.

Where l is the heat of fusion of a crystalline substance, m is the mass of the melting body and q is the quantity of heat required.

Pupils' attention should be drawn to the fact that while using this formula one should bear in mind that if the mass of the melting body is represented in kilogram the heat of fusion should be taken in kilocalories per kilogram. By

doing so, the quantity of heat q will be in kilocalories.

If the mass of the body is given in grams then l is taken in calories per gram and q is represented in calories.

Note : For a considerable period of time physics treated heat of fusion as latent heat of fusion. This was due to the fact that the real process associated with melting was not known and so it was called latent, since the energy absorbed by the body did not bring about an increase in the temperature of the melting substance. This outdated term—latent heat of fusion as well as a number of other physical quantities are still to be found in many textbooks.

Finally let us consider the third section of the graph namely section CD. The first question to be put to pupils is the following. In what aggregate state is naphthalene in section CD? In this section naphthalene is only in one state, namely, it is liquid. The second question will be how is the energy spent in the section CD? The energy absorbed by naphthalene in this section is spent in heating liquid naphthalene from the melting point t°_1 C to a higher temperature t°_2 C.

How can we calculate the quantity of heat spent in heating this liquid naphthalene ? This is the next question. It is possible by using the formula which the students already know:

$q=s.m\ (t_2—t_1)$, where S is specific heat of liquid naphthalene and m is the mass of the liquid naphthalene.

Note : While solving problems, pupils' attention should be drawn to the dependence of the specific heat of a substance on the aggregate state of the same substance. Thus, for instance the specific heat of water, as is known is equal to one, whereas the specific heat of solid water, *i. e.*, ice is smaller. It equals 0.5 cal/degree C.

At last, in solving problems on melting we have to consider problems connected with calculation of the quantity of heat required for melting a crystalline body taken at a temperature below its melting point, for instance, ice at the temperature of —5°C.

As is seen from the above analysis of the graph of the melting process, it is easy to solve this problem or other problems. In solving a problem the following analysis can be given.

To melt a crystalline body taken at a temperature below its melting point it is necessary to supply to it, the quantity of heat q_1 to heat it from its initial temperature t°_1 to its melting temperature t°_0 and the quantity of heat q_2 required to transform the crystalline substance into a liquid without changing the temperature t°_0.

Thus the total amount of heat will be $q=q_1+q_2$

where $q_1=s.\ m\ (t^o_0 - t^o_1)$ and $q_2=Lm$

$q=m.\ s.\ (t^o_0—t^o_1)+L.\ m$

Let us examine one particular problem. Calculate the quantity of heat required to transform 5 kilograms of ice taken at the temperature —2°C into water at the temperature of 40°C. In the first place it is necessary to convert the conditions of the problem from the original form into the form of conventional

abbreviated symbols :

$m = 5$ kg.

$S\,ice = 0.5 \dfrac{Kcal}{kg\ degree\ C}$

$t_0^o = -2°C$

$t_1^o = 0°C$

$S\,water = 1 \dfrac{Kcal}{kg.\ degree\ C}$

$t_2^o = 40°C$

$L = 80 \dfrac{Kcal}{kg}$

$q - ?$

$q = q_1 + q_2 + q_3$

where q_1 is the quantity of heat required to heat the ice from the initial temperature to its melting point,

$q_1 = S\,ice \times m\,(t_1^o - t_0^o)$,

q_2 is the quantity of heat required for the process of melting ice, without change in temperature, $q_2 = L.\ m$, and q_3 is the quantity of heat required to heat the water obtained from the ice from the melting point to the temperature of 40°C. $q_3 = S\,water \times m(t_2^o - t_1^o)$ substituting in formula (1) we obtain:

$q = q_1 + q_2 + q_3$

$= S\,ice.\ m\ (t_1^o - t_0^o) + L.\ m + S\,water.\ m\ (t_2^o - t_1^o)$

$q_1 = S\,ice.\ m\ (t_1^o - t_0^o)$

$= 0.5 \dfrac{Kcal}{kg.\ degree\ C} \times 5\ kg \times \{0° - (-2°)\}$

$= 0.5 \dfrac{Kcal}{kg\ degree\ C} \times 5\ kg \times 2°$

$= 0.5 \times 5 \times 2\ Kcal = 5\ Kcal$

$q_2 = L.\ m = 80 \dfrac{Kcal}{kg.} \times 5\ kg.$

$= 400\ Kcal.$

$q_3 = S\,water.\ m\ (t_2^o - t_1^o) = 1 \dfrac{Kcal}{kg\ degree\ C} \times 5\ kg\ (40° - 0°)$

$= 1 \dfrac{Kcal}{kg.\ degree\ C} \times 5\ kg \times 40°$

$= 1 \times 5 \times 40\ Kcal = 200\ Kcal$

$q = 5\ Kcal + 400\ Kcal + 200\ Kcal$

$q = 605\ Kcal.$

The study of the process of melting should result in acquiring by pupils skills in solving problems. It is important, therefore, that the teacher should (in

each lesson) train his pupils in solving problems available in the given teachers' guide and should include in the home task the solving of problems available in the exercise contained in the textbook.

After observation of the melting process, the same arrangement may be used for demonstrating the characteristics of the reverse process of crystallization of liquid naphthalene. For this purpose, the spirit lamp is removed from the arrangement while the test tube containing liquid naphthalene is placed in a vessel of cold water. As in the process of melting here in this process, too, the temperatures should be recorded on the classboard after equal periods of time and a graph of temperature against times should be drawn.

Pupils' attention should be drawn to the following facts:

1. Initially, a decrease in the temperature of liquid naphthalene to the temperature of crystallization is observed.

2. When temperature of crystallization is reached the temperature remains constant and crystallization of liquid naphthalene begins. The temperature remains constant until the liquid naphthalene has crystallized completely.

3. Finally the third part of the graph consists in the cooling of crystalline naphthalene accompanied by a decrease in its temperature.

Note : The teacher should bear in mind that the suggested arrangements for observing the melting process and crystallization is intended for laboratory use. It is evident, therefore, that not all the pupils will be able to see the changes naphthalene undergoes at such a small arrangement. Under the syllabus however pupils will later perform the same experiment in laboratory work. Therefore, this demonstration is a basis for clarifying the processes of melting and crystallization on the one hand and preparation of pupils for laboratory work on the other.

After this demonstration the same sequence as in the process of melting should be used in the interpretation of the individual portions of the crystallization process graph. This may be done in the form of a talk with pupils. To make it effective we put a number of questions to pupils and give them an opportunity to give their interpretation. After this the teacher suggests corrections and in conclusion gives the right answer to the question put by himself.

Question 1

What is the aggregate state of naphthalene represented in the section DE of the graph?

In this section naphthalene is in the liquid state as its temperature exceeds its melting point.

Question 2

What does happen to the temperature of the liquid naphthalene in the section DE ?

Its temperature decreases.

Question 3

What does accompany the cooling of liquid naphthalene ?

The process of cooling is accompanied by a release of the quantity of heat.

Question 4

What does happen with the internal energy of the cooling liquid naphthalene?

Its internal energy decreases.

Question 5

On what account does the internal energy of liquid naphthalene decrease?

Its internal energy decreases because of the decrease in the kinetic energy of the molecules.

When the body cools, the average speed of its molecules decreases with the decreasing temperature and consequently the kinetic energy of the molecules also decreases.

Question 6

How is it possible to calculate this decrease in internal energy ?

The decrease in the internal energy is equal to the quantity of heat released by the cooling naphthalene and therefore can be calculated by the following formula:

$q = S \times m\ (t_1^\circ - t_2^\circ)$

After that we pass over to the interpretation of the section EF of the crystallization graph.

Question 1

In what state is naphthalene represented by the section EF of the graph?

In this section naphthalene is in two states: crystalline and liquid. As time passes, the mass of crystalline naphthalene increases whereas the mass of the liquid decreases.

Pupils' attention should be drawn to the similarity and dis-similarity of these two identical sections in the processes of melting and crystallization.

The process of crystallization as well as the process of melting occurs for one and the same substance at one and the same temperature, *i.e.*, the melting

point and the crystallization point of one and the same substance are the same. For instance, for naphthalene they are 80° C, for ice 0° C etc.

Another similarity consists in the fact that both the process of melting and the process of crystallization occur at a constant temperature. The dis-similarity of these two reverse processes consists in the fact that the process of melting is accompanied by consumption of some quantity of heat whereas the process of crystallization is accompanied by release of the same quantity of heat into the surroundings.

It is important to draw pupils' attention to the fact that a crystalline substance at the melting point (or crystallization point) can be in two aggregate states—crystalline and liquid.

Therefore it is impossible to give an answer to the question : In what state naphthalene at 80° C is, and in what state water at 0° C is? Since at these temperatures a substance can be in two aggregate states—crystalline and liquid.

Also it is impossible to identify the process which is taking place whether it is crystallization or melting, if we know only the temperature of the system (melting or crystallization). However, we can easily understand that if we know that the crystalline substance is at the point of crystallization and a certain quantity of heat is being released, the substance is crystallizing. That this is true is seen from the experiment since in the section EF of the graph, the mass of crystalline naphthalene increases whereas the mass of liquid naphthalene decreases, *i e.*, the reverse relationship is observed between the mass of these two states during the process of melting.

After this remark let us go on with the analysis of this process in the section EF of the graph.

Question 1

What happens to the temperature during the entire process of crystallization?

The temperature remains constant as during the process of melting.

Question 2

What happens to the kinetic energy of the molecules during crystallization?

The kinetic energy of the molecules remains constant during the entire process, since unless the temperature changes the average speed of the molecules remains constant and consequently the kinetic energy of the molecules also remains constant.

Question 3

What happens to the internal energy during the process of crystallization?

The amount of the internal energy decreases since during crystallization a certain quantity of heat is released into the surroundings.

Question 4

On what account does the amount of the internal energy decrease during the process of crystallization ?

Since the kinetic energy of the molecules remains constant in this case, it follows that the internal energy decreases on account of the decrease in the potential energy of the molecules.

In fact when the crystals are formed, the distance between the molecules decreases and consequently the potential energy of the interaction between molecules also decreases.

On the basis of this the teacher can introduce the concept of the heat of crystallization. The heat of crystallization shows what quantity of heat is released by one gram of a substance when it changes from a liquid state into a crystalline state without any change in the temperature.

The heat of crystallization and the heat of fusion for one and the same substance are the same. Thus, for instance, the heat of fusion of ice is equal to 80 Cal g and the heat of crystallization of water is also equal to 80 Cal g' etc. (if the two processes take place under the same pressure).

Finally we pass over to the analysis of the last section FG of the graph.

Question 1

In what state is the naphthalene as represented by this section of the graph?

It is in the crystalline state.

Question 2

What happens to crystalline naphthalene in the section FG ?

Crystalline naphthalene cools.

Question 3

What happens to the internal energy of crystalline naphthalene ?

Its internal energy decreases.

Question 4

Why does the internal energy of crystalline naphthalene decrease?

The internal energy decreases on account of the decrease in the kinetic energy of its molecules because with a decrease in the temperature the average speed of the molecules must decrease and consequently the kinetic energy of the molecules also decreases.

Question 5

How can we calculate this decrease in the internal energy ?

This decrease in the internal energy is equal to the quantity of heat released by the naphthalene when it is cooling. Consequently this decrease is given as $q=S.\ m\ (t_1^\circ - t_2^\circ)$.

IV. *Evaporation*

The processes of evaporation and condensation are analysed in the same way as the processes of melting and crystallization, namely,

(a) Demonstration of the phenomenon of evaporation and condensation.

(b) The significance of these phenomena in nature and technology (natural regulation of the climate by the circulation of water in nature, evaporation of freon in refrigerators, etc.).

(c) Clarification of the molecular kinetic picture of the process of evaporation and condensation.

(d) Experimental proof of the dependence of rate of evaporation on various factors.

(e) The interpretation of the dependence of evaporation rate on a number of factors.

(f) Interpretation of evaporation and condensation processes in terms of internal energies.

With a view to having a more correct approach to the sub-topic namely boiling, it is necessary to give a general definition of the process of vaporization as a process of transition of a substance from the liquid state into the vapour state.

Vaporization can take place in two ways:

Evaporation and boiling. Therefore, we shall first consider the process of evaporation.

The process of evaporation of a liquid is a widespread phenomena among other natural phenomena in daily life and technology.

It is possible to begin the first lesson on this sub-topic by putting this question to pupils.

Give examples from your own observations of transformation of a liquid into vapour.

Having discussed the examples given by pupils the teacher gives some more examples, for instance, on a warm summer day, the water sprinkled in the streets dries up quickly, *i.e.*, it evaporates; wet clothes in the open air dry within a short time, *i.e.*, the liquid contained in the clothes evaporates: perfume in uncorked bottles disappears after some time, *i.e.*, it evaporates, etc.

A very large quantity of water evaporates from natural water reservoirs, the surface of the ocean and seas. The total amount of water evaporating from the surface of the Earth in a year is about 518,600 cubic kilometres in volume. This enormous amount of water is enough to cover the whole surface of the earth with a layer of more than 1 metre thick,

It follows that in atmospheric air there is always a certain amount of water vapour. Circulation of water in nature is of vital importance for all the living bodies on the earth, *i.e.*, for people, animal and plants.

On account of evaporation from water reservoirs, the humid air becomes heated when it touches the warm surface of the earth, becomes lighter and goes up into the upper layers of the atmosphere. There this humid air cools and the reverse process (condensation) takes place, *i.e.*, transition of water from the vaporized state into the liquid state. Therefore, the moisture evaporated from the natural water reservoirs is compensated back to the earth as a fall out.

After these general discussions aimed at encouraging pupils' interest in learning this sub-topic it is necessary to show a number of simple and convincing demonstrations illustrating the existence of the processes of evaporation and condensation.

For this purpose it is possible to recommend to show the evaporation from some volatile liquid for instance, ether, spirit or petrol. With the help of a pipette one or two drops of ether are placed on a white sheet of paper and with the help of an illuminated screen the quick drying up of the spot is demonstrated.

After the demonstration pupils' attention should be drawn to the existence of the processes of transition into the vaporized state not only of liquids but also of solids. Evaporation of some solid bodies can be easily detected by smell. Thus it is very easy to detect the evaporation of naphthalene and camphor. For a visual observation of evaporation of a solid body, it is recommended to show the evaporation of a small amount of iodine crystals. For this purpose iodine crystals are placed at the bottom of a round bottomed flask. After heating the flask slowly with the help of spirit lamp for some time pupils will see formation of intense violet coloured vapours of iodine in the flask.

To demonstrate the reverse process namely condensation of water vapour, it is possible to use the arrangement shown in the textbook.

After pupils have become convinced of the existence of evaporation processes it is necessary to pass over to the explanation of this process in the light of the molecular kinetic theory.

First pupils' understanding of the thermal motion of molecules should be somewhat enlarged.

Pupils had already been told that the temperature of a substance depends on the speed of thermal motion of the molecules.

It should be noted that speaking of the dependence between the speed of the thermal motion of the molecules and the temperature of the body we mean the average speed of the molecular thermal motion. This means that most of the molecules of the given body move at an average speed which determines the temperature of the body.

But besides these molecules that move at an average speed at a given temperature there can exist some molecules whose speed is less than the average speed and some molecules moving at speeds exceeding the average speed. Proceeding

from this it is possible to explain the mechanism of the process of evaporation of liquids. The molecules that are inside of this liquid are surrounded by the molecules of the liquid from all sides (see picture in the textbook) Each such molecule experiences the interaction of all the molecules located within the sphere of radius (R) of molecular interaction. They also have frequent collisions with the other molecules in the liquid and are constantly deflected in their motion. Therefore, such molecules located in the internal layers of the liquid cannot easily escape from the liquid surface. Only those molecules which are located in the surface layer of the liquid can go out of the liquid surface. For these molecules the sphere of molecular interaction is partially above the liquid and partially within the liquid. But the force of attraction due to the molecules in the liquid is much greater than that due to vapour molecules above the surface. Therefore, there is a net cohesive force downwards. Therefore, the molecules of the liquid which are located in the surface layer or in the layers close to the latter and which move at great speed and consequently possess a large amount of kinetic energy. They have a chance to overcome the cohesive forces and fly far beyond the surface of the liquid. This results in the formation of the vapours of this liquid.

The following questions may be put to pupils after that.

Since the process of evaporation is of great practical importance, it is necessary to find out on what the rate of this process depends? For this purpose it is necessary to analyse a few examples from daily observations and then to prove experimentally on what factors the rate of the process of evaporation depends.

(a) The rate of evaporation depends on the surface area of the evaporating liquid. First the teacher puts the following questions to pupils.

Give examples illustrating that the rate of evaporation of liquids depends on the surface area of the evaporating liquid. If we compare the time necessary for evaporation of the water contained in a bucket and the time of evaporation of the same amount of water poured on to the surface of the floor we shall easily see that water will evaporate more quickly from the surface of the floor the area of which is much larger than the surface area of the water in the bucket.

If we want to dry up some fruit quickly for instance, a green mango, we cut it into small pieces. The surface area of the uncut mango is less than that of these pieces together. The time of the drying of fruits depends upon the rate of evaporation of the water.

Demonstration 1

Let us show that actually under other similar conditions the rate of evaporation depends on the surface area of the evaporating liquid.

In this as well as in the subsequent demonstrations it is important that attention should be drawn to the conditions of the experiment In particular in this demonstration by other similar conditions we mean the following. Suppose we

have same liquid at the same temperature in two open vessels of different cross-sections. Now we want to know the amounts of evaporated liquids from these two vessels during the same time. In brief the conditions can be written on the classboard in the following way:

Conditions :

$t_1^\circ = t_2^\circ$

$P_1 = P_2$

$S_1 > S_2$

$t_1 = t_2$

to prove: $m_1 < m_2$

The demonstration itself is carried out as follows: A test tube and a basin are taken and an equal amount for instance, 10 drops of highly volatile liquid (ether or spirit) are put into them. The experiment shows that in fact under other similar conditions ether will evaporate more quickly in the basin than in the test tube since the surface area of the basin exceeds that of the test tube.

Note : While the demonstration is being carried out pupils should copy in their note books what the teacher draws on the classboard.

After this we pass over to the consideration of the dependence of the rate of evaporation on the temperature of the evaporating liquid. We begin by putting the following question to the pupils:

Give examples showing that the rate of evaporation under other similar conditions depends on the temperature of the evaporating liquid.

For instance, it is common knowledge that in a hot summer day during the monsoon period water in the streets dries up more quickly than water on a cloudy day or than in winter.

All the pupils have observed that clothes dry up more quickly on a hot day than on a cloudy day.

After this, the teacher can pass over to the second demonstration and show that the rate of evaporation depends upon the temperature of the evaporating liquid when all other conditions are the same.

Demonstration 2

In brief the conditions can be written in the following way :

$t_1 = t_2$

$S_1 = S_2$

$P_1 = P_2$

$t^\circ_1 > t^\circ_2$

to prove : $m_1 > m_2$

Two similar vessels namely two basins are taken into which equal volumes of water are poured. However, in one of the vessels the temperature of the water is 25°C to 30°C while in the other 85°C to 90°C. Both vessels are placed and balanced

on the demonstration balance. After some time it can be observed that the pan with the cooler water overweighs the pan with the hot water. Consequently in one and the same period of time more hot water evaporated than cold water.

After this we pass over to consider the dependence of the rate of evaporation on the properties of the liquid itself.

The teacher puts the following questions to pupils : Give examples showing that the rate of evaporation depends on the properties of the liquid itself. It is well known that if a bottle with ether or spirit is not corked well it will evaporate quickly whereas under the same conditions water will take longer time to evaporate.

To prove the dependence of the rate of evaporation on the properties of the liquid, the following experiment is performed.

Demonstration 3

Conditions:

$t_1=t_2$

$S_1=S_2$

$t_1^\circ=t_2^\circ$

ether P_1, P_2 water

To prove : $V_1>V_2$

Equal amounts of water and ether (or spirit) are poured into two small crystallizers, respectively. The vessels are put on the pans of the balance and balanced. After sometime the pupils will observe that the plates are not in equilibrium. The pan with the vessel containing water overweighs the other. Consequently within the same period of time ether (or spirit) evaporated more than water.

Thus, under similar conditions the rate of evaporation depends on the properties of the liquids. Therefore, some liquids are called volatile. To such liquids belong ether and spirit and other liquids. Other liquids are called non-volatile.

Finally, pupils should be shown that the rate of evaporation depends, under other equal conditions, upon the fact whether evaporation occurs in open or closed vessels.

Pupils can give various examples from their experience showing that the rate of evaporation depends on the presence of air currents over the evaporating surface. It is well known that clothes dry up more quickly in a windy day than when the weather is quiet.

Conditions:

$t_1=t_2$

$S_1=S_2$

$P_1=P_2$

(Open vessel) $t_1^\circ=t_2^\circ$ (corked vessel).

to prove: $m_1 > m_2$

The dependence of evaporation on the speed of vapour removed from the surface of the liquid can be demonstrated with the help of the following arrangement : Put two basins containing equal amount of ether at the same temperature on the pans of a demonstration balance. The mouth of one basin is closed while that of the other is kept open. Bring the balance in equilibrium. After some time, the pan with closed basin goes down. From this, it is concluded that the rate of evaporation from the open vessel is more because of the removal of vapours by the air current. At the end, we can show a very important effect of evaporation on the evaporating liquid that due to the evaporation itself the temperature of the evaporating liquid decreases. For this, a manometer is connected by means of rubber tubes with two round bottomed flasks. A piece of flannel cloth moistened with ether is placed on the flask. The experiment shows a change in the level of the liquid in the manometer. The change in the level can be explained only by the decrease of temperature of the air in the flask. Consequently this experiment makes one to conclude that the process of evaporation is accompanied by a decrease in the temperature of the evaporating liquid.

Retention :

1. What does show the first part of the graph?
2. In what state is the naphthalene in the first part of the graph?
3. What happens to the temperature during the whole process of melting?
4. In what state is naphthalene in the second part of the graph?

Home task.

Lesson No. 3

Topic : The process of melting and crystallization from the point of view of molecular kinetic theory.

Aim : To explain the students regularities in the process of melting and crystallization.

1. *Questions to pupils :*

1. What is the basic point of molecular kinetic theory?
2. What constitutes the internal energy of a body?
3. On what does the kinetic energy of molecules depend?
4. On what does potential energy of the molecules depend?
5. What happens to the temperature of a body during the heating of crystalline naphthalene?
6. Upto what degree the temperature of naphthalene is increased by heating?
7. How will you name the temperature at which the body melts at normal atmospheric pressure.
8. Does the temperature of naphthalene increase during the process of melting ?

Explanation of the regularities of the process of evaporation from the point of view of molecular kinetic theory

From the experiments students have seen that liquid evaporates (other conditions being equal) more quickly when the area of the free surface of the liquid is greater. Students already know that the molecules, which have sufficient speeds and lie on the surface of the liquid can escape from the surface of the liquid. Therefore, greater the free surface of the liquid is, larger is the number of molecules on the surface, and consequently more is the number of molecules which can overcome the force of interaction between molecules and form more volume of vapour of this liquid. So the experiment and theory show that when area of the surface of the liquid is greater, the liquid evaporates more quickly. It is also easy to explain to students the following regularities of the process of evaporation.

Students have seen from the experiment that the rate of the process of evaporation depends on the temperature of the liquid; in other words we can say that higher the temperature of the liquid the greater is the speed of the process of evaporation. Students already know that if temperature of the liquid is greater then also is greater the average speed of the thermal motion of molecules. The amount of kinetic energy of molecules depends on the average speed of the molecules, *i.e.*, more the average speed of molecules more is the value of kinetic energy of molecules. So by increasing the temperature of the liquid the amount of kinetic energy of the molecules is increased and consequently increases the number of the molecules which can overcome the force of interaction between molecules and escape from the surface and form the vapour of this liquid. From this we can draw the following conclusions. The rate of the process of the evaporation increases by increasing the temperature of the liquid.

From the third demonstration students have seen that other conditions being equal, one type of liquid evaporates quicker than another. The molecular kinetic theory explains this fact that different liquids possess different values of the interacting forces between the molecules. In other words it means that for evaporation in some liquids molecules require less value of kinetic energy to overcome the force of interaction. Therefore, at the same temperature in some liquids there are greater numbers of molecules which can overcome the force of interaction and form the vapour of this liquid. So in this case, we see that other conditions being equal, the rate of the process of evaporation, depends on the property of the liquid itself.

From the next demonstration the students have seen that the liquid evaporates quickly if there is a motion of air above the surface of the liquid. The teacher must remind the students that along with the process of evaporation there is a reverse process, condensation of the vapour into the liquid. If evaporation takes place in the closed vessel, the molecules of the formed vapour by their thermal motion will come near to the surface of the liquid. In this case, by the action of

the force of interaction, the molecules of the vapour will again drop into the liquid. This process of condensation can be decreased if the air blows over the surface of the evaporating liquid. The formed molecules of vapour are removed from the surface of this liquid by the action of moving air and do not allow the conditions favourable to the process of condensation. So other conditions being equal, the liquid evaporates quickly if there is a motion of air over the surface of evaporating liquid.

After explanations of regularities of the process of evaporation on the basis of molecular kinetic theory, it is necessary to proceed to more difficult points of this sub-topic *e.g.*, to explain the process of evaporation from the point of view of internal energy concept. This question should be started by considering separately examples from everyday life of students in which we observe cooling due to evaporation of liquids. A few examples are given below:

1. Pupils feel cold when they come out of the river after swimming.
2. If we wet the finger with ether we feel the cooling of finger.
3. Water in an open vessel kept in the room always has less temperature than the temperature of the air in the same room.

From this or other examples like these, it follows that the process of evaporation of liquids is associated with cooling of evaporating liquid. After these examples it is desirable to show an effective demonstration.

*Place a small glass beaker with a small volume of water on the demonstration table. Place a test tube with 1 or $1\frac{1}{2}$ cubic centimetres ether into the beaker with the help of a rubber tube, blow the air through the ether. In this case the ether quickly evaporates and at the same time we can observe that some water in the vicinity of the test tube is frozen in the beaker. From these examples and this demonstration it follows that the process of evaporation of a liquid requires energy.

Because during the process of evaporation this value of energy is not taken out from any other source, it is taken only from the internal energy of the evaporating liquid itself. In fact, cooling of liquids during the process of evaporation means decreasing the value of internal energy of the evaporating liquid. The students already know that internal energy consists of sum of kinetic and potential energies of the molecules. Therefore, we can exactly say that process of evaporation of liquid is associated with the decreasing of internal energy on account of the decrease in the kinetic energy of the molecules of the liquid because the temperature of the liquid is determined by the value of average speed of the thermal motion of molecules. The students already knew of the mechanism of the process of evaporation of liquids which consists of the emission of molecules having sufficient value of kinetic energy, from the surface of the liquid. Consequently,

*The success of this demonstration depends upon the temperature of the season. In summer season, the demonstration at page 226 is preferred.

molecules possessing high speed and enough kinetic energy leave the surface of the liquid. Therefore, the molecules, in the liquid will possess less speeds and the average speed of all molecules of the liquid decreases leading to the decrease in the temperature of evaporating liquid. To impart a good knowledge and skills to the students during the study of this sub-topic the teacher must give in each lesson some qualitative and experimental problems. For this purpose, we have given a large number of different types of problems in the guide.

BOILING

The order of discussion for the explanation of the process of boiling is more or less in the same way as in the process of melting crystalline bodies as follows:

1. Consideration of the process of heating and boiling water.
2. Consideration of the graph of the process of heating and boiling.
3. Mechanism of the process of boiling of water.
4. Introduction of the concept of "heat of vaporization".
5. Formula for calculating the quantity of heat required for the vaporization of a certain amount of liquid.
6. Dependence of the boiling point on the outside pressure.
7. Quantity of heat which a certain amount of vapour gives off during the process of condensation.

At the beginning of the first lesson of the sub-topic "process of boiling", it is necessary to remind the students that the process of vaporization—change of the state of substance from the liquid to the vapour, is possible in two ways: (1) by evaporation and (2) by boiling. The first process was discussed in the previous sub-topic. Therefore, we shall now pass on to the second process—boiling. In spite of the fact that the process of boiling is familiar to the students from every-day life observation, we shall start this sub-topic from the demonstration of the process of boiling in the class room.

For this purpose place a stand on the demonstration table and fix a flask filled with water to it. From the same stand suspend a thermometer with the help of a thread in such a way that the ball of the thermometer must be into the water of the flask but does not touch its bottom. Place a spirit lamp under the flask and observe the process of heating and boiling water.

In addition to this, students have laboratory work and observation of heating and boiling of water in the syllabus. Therefore, this demonstration* can help the students to carry out this laboratory work with more efficiency. Some points which they cannot observe in this demonstration, can be visualized in their own

*This demonstration like the demonstration of the melting of naphthalene does not enable all the students of the class to observe very well this process which consists of heating and boiling. At the same time this demonstration is very essential because it is the basis of explanation of new material which is to be given by the teacher.

laboratory work. During the observation of this demonstration of heating and boiling water, the teacher together with the help of students, should measure the temperature of the water after equal period of time and then on the basis of these data he may plot a graph of the process of heating and boiling on the blackboard. During the period of observation, the teacher must draw the attention of the students to the following specific features of this process:

1. At the beginning of this demonstration the teacher should draw the attention of the students that at the bottom and the walls of the flask there are bubbles of air. This air is dissolved in water and we observe this air-like tiny bubbles on the walls.

2. During the process of heating, the process of evaporation of liquid takes place in the small bubbles of air. So, these bubbles consist of small amount of air and some amount of the water vapour.

3. With the increase in the temperature of water, the process of evaporation into the bubbles is accelerated, which in turn increases the pressure of the water vapour in these bubbles. This increase in pressure of water vapour in the bubbles causes an increase in the volume of each bubble.

4. Due to increase in the volume of these bubbles, the force of buoyancy which acts upon these bubbles is also increased.

5. The buoyant force on these bubbles, overcomes the force of interaction between bubbles and walls of this flask and the bubbles rise to the surface of the liquid, break up and form water vapours.

6. At the beginning of this process, bubbles mainly consist of air, and after some time the bubbles will contain water vapours.

7. When the bubbles go up to the surface of the liquid, by the action of buoyant force, new bubbles are formed at the same points of walls and the same process continues afterwards.

8. When the water reaches the temperature equal to 100°C, it gives off water vapours violently from the whole volume of the liquid. The temperature, at which the liquid starts boiling at normal outside pressure, is called the boiling point. Different liquids at the normal atmospheric pressure, start boiling at different but definite temperatures.

9. The boiling of the liquid starts when the pressure of vapour of the liquid in the bubbles becomes equal to the outside pressure.

10. Throughout the process of boiling, the temperature remains constant which is equal to the temperature of the boiling point of the liquid.

After discussing the process of heating and boiling, we would pass on to the analysis of the graph obtained in this experiment (this graph you can see in the text-book). Now we shall concentrate on the consideration of specific features of this graph by putting questions to the students:

1. What characterises the first part AB of this graph of boiling of water from the initial temperature up to the temperature of its boiling point—100°C.

2. What causes the heating of water.

Heating of water is caused by the quantity of heat which is given off during the process of burning of the spirit.

3. What happens to the amount of internal energy of water in the part AB of the graph ?

Internal energy of water increases in the part AB of the graph.

4. On what account does the internal energy increase in the part AB of the graph?

Internal energy of the water in the part AB of the graph increases on account of increase in the kinetic energy of its molecules, because with the increase in the temperature of the liquid, the average speed of the molecules increases; leading to an increase in the kinetic energy of its molecules.

5. What state of water is represented by the part AB of the graph ?

The part AB represents the liquid state of water.

After this, we pass on to the consideration of the next part, BC of the graph.

1. What characterises the part BC of the graph ?

The part BC characterises the process of boiling of water.

2. What happens to the temperature of water during the process of boiling?

During the process of boiling of water, temperature remains constant which is equal to the temperature of its boiling point.

3. What state of water is represented by the part BC of the graph?

In part BC of the graph, water is in two states: liquid and vapour. When we go from point B to point C of the graph, the mass of vapour produced increases while the mass of the water in liquid state decreases.

4. From where is the energy required in the process of boiling obtained?

Energy required in the process of boiling is supplied by burning the spirit.

5. What happens to the amount of internal energy of the mixture of water and water vapour in the part BC of the graph ?

The internal energy of the mixture in this part of the graph increases too.

6. What constituent of the internal energy does increase in the part BC of the graph?

Because the temperature during the process of boiling remains constant, the amount of kinetic energy of molecules remains constant too. So it is easy to understand that increase in the total amount of internal energy can be only due to the increase in potential energy of the molecules. Considering this part of the graph, it is desirable to carry out an analogy between this process and the process of melting of crystalline substances. The students already know that in order to change the state of solid bodies into the liquid it is necessary first to heat the solid bodies till they reach the temperature of melting point and then give some more quantity of heat which is required to melt the crystalline body without changing its temperature. This quantity of heat does not increase the temperature because it goes to increase the potential energy of molecules of the crystalline substance or

in other words we can say that this quantity of heat goes to overcome the force of interaction between molecules of crystalline substance and to break the crystal lattice. Exactly analogous process takes place in vaporization of the boiling water. After the liquid reaches the temperature of boiling point, the quantity of heat which is required to change the state of the liquid to the vapour goes to overcome the force of interaction between molecules, so it goes to increase the potential energy of the molecules. On the basis of the analogy we can introduce the concept of the heat of vaporization.

Heat of vaporisation is the quantity of heat which is required to transform one gram of the liquid at its boiling point into the vapour without changing the temperature. The heat of vaporization as well as the heat of fusion are given in the tables of constants and can be expressed in following units:

$$\frac{\text{Cal}}{\text{g}} \quad \text{or} \quad \frac{\text{Kcal}}{\text{kg}}$$

Therefore if we denote the heat of vaporization by the letter L, and mass of the vapour produced during the boiling by letter m, the quantity of heat which is required in the process of vaporization can be calculated by the following formula:

$$q = L.\,m.$$

If the temperature of the liquid is less than the temperature of boiling point, the quantity of heat which is required for the process of vaporization can be calculated by the following formula:

$$q = q_1 + q_2$$
$$q = S.\,m.\,(t_2^\circ - t_1^\circ) + L.m.$$

In this formula the first component q_1—is the quantity of heat which is required to heat the liquid from initial temperature upto the temperature of boiling point; the second component q_2— is the quantity of heat which is required for the process of vaporization without changing the temperature.

After the explanation of the process of boiling it is desirable to carry out comparison between the process of evaporation and boiling. First draw the attention of the students to the common points of these two processes:

1. Realized in two ways—by evaporation and by boiling are the two types of vapo rization.

2. It is necessary to spend some amount of energy for the process of evaporation as well as for the process of boiling.

Then the difference between these two processes should be pointed out.

1. In Evaporation—the process of vaporization takes place at any temperature of the liquid while in the process of boiling—the process of vaporization takes place at a definite temperature of the liquid at normal outside pressure.

2. In Evaporation—the process of vaporization is only from the surface of the liquid while in boiling vaporization is from the total volume of the liquid.

3. Energy which is required for the process of vaporization by evaporation is taken from internal energy of the evaporating liquid itself while in the process of

boiling this amount of energy is taken from outside source of heat.

After explaining the process of boiling and carrying out laboratory work of this sub-topic by the students, the teacher must give special lesson for solving the problems on the process of boiling. The problems in this sub-topic are more difficult than the problems of previous sub-topic because in this sub-topic we must consider quantitative problems which are connected with calculations and take more time than the problems on the sub-topic of evaporation.

In the same order the teacher can discuss the reverse process of vaporization—the process of condensation. The order of explanation will be as follows:

1. Consideration of some examples of condensation of vapour from everyday observations of the students.
2. Demonstration of the process of condensation of water vapour.
3. Graph of the process of condensation.
4. Demonstration showing the process of condensation associated with giving off some quantity of heat.
5. Equality of heat of vaporization and heat of condensation for the same substance.
6. The analogy between process of condensation and process of crystallization.
7. Solving of problems on condensation of vapour.
8. Dependence of the boiling point of a liquid on the value of outside pressure.

(*a*) Boiling at less than normal outside pressure.

(*b*) Boiling at higher than outside pressure.

The explanations of the details of these sub-topics are not taken up. We want only to stress upon the basic experiments of this sub-topic.

In what way can we show experimentally that the process of condensation of the vapour is associated with the giving off some quantity of energy to the surroundings?

For this purpose we may arrange a simple apparatus. Place a flask with boiling water connected with the test tube which is put in the beaker with the cold water on the demonstration table. Place a thermometer in the beaker. The students can observe that when the water vapour comes in the test tube it is cooled and condensed producing the water into the test tube. By observing the scale of thermometer it is easy to find out that the temperature of water in the beaker increases. This increase in the temperature of cold water in the beaker is the result of two processes: some quantity of heat which is given off during the process of condensation and some quantity of heat which is given off by cooling the hot water formed by vapours. For clarifying further we must show to the students a second demonstration. In the first demonstration note the volume of the water which is formed from the vapours in the test tube and note the amount of the increase in the temperature of water in the beaker as well as its volume and initial temperature. We can show the second demonstration as follows:

Place the same beaker with the same volume of cold water, and same initial temperature on the demonstration table. Put the test tube with the same volume of hot water (100°C) as in the first demonstration and observe the increase in the temperature of water in the beaker by only one process—process of cooling hot water which is in the test tube. The result of this second experiment shows that the increase in the temperature in the second demonstration is less than in the first demonstration. From these two demonstrations we can draw the conclusion that in the first case more quantity of heat is given off as compared to the second case, because in the first case the quantity of heat given off consists of two components :

(I) Quantity of heat, which is given off in the process of condensation and (2) Quantity of heat which is given off by cooling of hot water formed from the water vapours.

So this experiment shows that the process of condensation is associated with the giving off some quantity of heat. This process of condensation is a change in the state of substance from vapour to the liquid and takes place without any change in temperature, because the temperature of the water vapour is 100°C and after the process of condensation it is transformed into water which has the same temperature, *i.e.*, 100°C. The process of vaporization is associated with absorption of some amount of energy, while the reverse process, *i.e.*, condensation is associated with liberation of same energy. Theory and experiment show that the heat of vaporization and heat of condensation of the same substance are equal to each other, for example, heat of vaporization of water at 100°C is equal to 539 calorie per gram and heat of condensation of water vapour at 100°C is also equal to 539 calorie per gram. Therefore, in the textbook only the table of the values of heat of vaporization for different substances is given. After this the teacher must explain the dependence of the boiling point on the value of outside pressure. The students can clearly understand it from the following demonstration. For this purpose a test tube with a small volume of water is fixed to the stand. The test tube is closed and connected to the rubber bowl. Heat the test tube with a spirit lamp and show the process of boiling at the normal atmospheric pressure. Then show to the students that if he compresses the rubber bowl by his hand, the value of the pressure inside the test tube is increased and immediately the boiling of water stops.

From this experiment we can draw the conclusion that the boiling point is increased if the outside pressure is increased When the teacher releases his hand from the rubber bowl some value of air and water vapour goes into the pear and consequently the value of pressure inside the test tube is decreased The students can observe that due to this decrease in pressure, the water again starts boiling. Thus we can also draw the conclusion that the point of boiling is decreased if outside pressure is decreased. This dependence of boiling point on the value of the outside pressure is not a specific feature of water only but it is a specific feature of

all types of liquids. We can link this dependence of boiling point upon the value of outside pressure with the definition of the process of boiling which was done at the beginning of the study of this sub-topic. The students know that the process of boiling of the liquid starts when the pressure of the vapour of the liquid in the bubbles becomes equal to the value of outside pressure So this is quite clear that the boiling point depends on the value of the outside pressure. After this the teacher must pass on to the consideration of similar examples from technology and nature, where the boiling of liquid is observed at low and high pressures.

I. *Melting and Crystallization*

1. Why do we prefer spirit thermometer to the mercury thermometer for measuring outdoor temperature on the high mountains.
2. Copper, iron and lead balls with equal masses were put into boiling water and then taken out and placed on the piece of the flat wax. Which ball melts the wax more?
3. Why is it not possible to use a small solderer for the soldering of a big massive piece of copper or iron?
4. Explain on the basis of molecular kinetic theory why the temperature during the process of melting and crystallization does not change?
5. Two pieces, one of aluminium and another of copper with the mass of 1 kilogram each, are heated to the temperature of melting. For which of these two pieces more quantity of heat is required?
6. What quantity of heat is required for melting 100 grams of iron at its temperature of melting?
7. What quantity of heat is required for melting 10 grams of naphthalene, gold and iron, at their respective melting points.
8. What quantity of heat is required for melting 1 gram of copper at the temperature of 27°C ?
9. What quantity of heat is required for melting 10 grams of lead at the temperature of 42°C?
10. What quantity of heat is required for melting 4000 kilograms of iron, if initial temperature of iron is equal to 30°C?
11. What quantity of heat is given out during the process of crystallization and cooling up to 60°C by 10 grams of liquid silver given at the temperature of its melting?
12. What quantity of heat does a piece of ice with mass of 217 grams take from surrounding air for the process of melting if the initial temperature was -5°C?
13. What quantity of heat is required by a plate of lead which has the size $2\times4\times10$ cm during the processes of heating and melting if the initial temperature is 27°C.

14. How many calories of heat is required for transforming two kilograms of ice into water given at the temperature of 0°C and heating the water formed up to 40°C ?

15. 100 grams of lead with the temperature at 427°C is cooled to the temperature of point of crystallization and then is cooled upto the temperature of 27°C. What quantity of heat is given off to the surrounding air? Specific heat of melting lead is equal to

$$0.04 \frac{\text{calorie}}{\text{gram degree C}}$$

16. Determine the thermal efficiency of a heater in which 80 grams of kerosene was spent in order to melt and heat, up to the boiling temperture, 2 kilograms of ice given at 0°C.

17. What is the value of the thermal efficiency of the melting stove in which 36 grams of bituminous coal is spent for melting each kilogram of copper with initial temperature of 83°C.

18. Determine the thermal efficiency of a melting stove in which 40.6 kilogram of bituminous coal is used for melting 500 kilograms of iron. The initial temperature of the iron is equal to 40°C.

II. *Evaporation and boiling*

1. One beaker with a small volume of ether has a temperature of 20°C. The second beaker is full with the same volume of water at the same temperature. After some time put two thermometers into each beaker and note the temperature. Which of the thermometers will show less temperature?

2. Why does grass dry more quickly by the windy weather than during the quiet weather?

3. Why do we feel cold when we come out of the river after swimming ?

4. In two similar plates pour the same volume of soup. In one, the soup is viscous and in the other it is thin. Which of the soups will be quickly cooled and why ?

5. Why does moist wood burn badly than the dry wood?

6. Why do the people living in high hills, while boiling meat in water, close the vessel and put on the top some heavy stones?

7. Why does water evaporate slowly in the bottle if it is closed tightly with a cork.

8. Which of the two possesses more internal energy : 1 gram of water at 100°C or 1 gram of water vapour having the same temperature?

9. What quantity of heat is required for heating 10 grams of water to its boiling point and converting the whole of it into vapour ?

10. What quantity of heat was spent to heat 0.75 kilograms of water at 20°C (up to 100°C) if during boiling, 250 grams of water is transformed into the

water vapour ?

11. What quantity of heat was spent for heating 10 kilogram water from 5°C up to 100° C, if by the boiling, 400 grams of water is transformed into the water vapour ?

12. What quantity of heat is given off by the condensation of 10 kilograms of water vapour at 100°C and cooling the water formed up to 20° C ?

13. What quantity of heat is required for melting 1 kilogram of ice, if the initial temperature was 0° C and boiling the converted water to the vapour at 100° C?

14. What quantity of heat is required for melting 2 kilograms of ice at −10° C and for the process of heating and vaporizing the whole volume into vapour?

15. What quantity of ice at 0° C can be melted by the quantity of heat which is given off by the process of condensation of 8 kilograms of water vapour at 100° C and normal pressure?

TOPICAL PLAN

No. of lesson	Date of the lesson	Topic of the lesson	Method to carry out the lesson	Demonstration	Home task
1	2	3	4	5	6
1.		Crystalline and amorphous bodies.			
2.		Process of melting and solidification of crystalline substances.			
3.		Consideration of the graph of the process of melting and crystallization.			
4.		Laboratory work, observation of the process of heating and melting naphthalene.			
5.		Heat of fusion and heat of crystallization.			
6.		Solving problems on the process of melting and crystallization.			
7.		Evaporation and condensation in nature and technology.			

1	2	3	4	5	6
8.		Dependence of the rate of evaporation of liquids on different factors.			
9.		Consideration of the regularities of the process of evaporation from the point of view of molecular kinetic theory.			
10.		Process of boiling water.			
11.		Explanation of the graph of the process of boiling. Heat of vaporization.			
12.		Laboratory work, observation of the process of heating and boiling water.			
13.		Solving problems.			
14.		Process of condensation.			
15.		Heat of condensation.			
16.		Boiling at the higher and lower outside pressure.			
17.		Solving the problems of total topic.			
18.		Control testing of the knowledge and skills of students of this topic.			

Detailed Plan of Each Lesson of the Chapter

Lesson No. 1

Topic : Crystalline and amorphous bodies.

Aim : To explain the very important points of the structure of the crystalline bodies.

I. *Plan of presentation of new material :*

1. Three aggregate states of the substance in nature.
2. Dependence of aggregate state of substance on its temperature.
3. Two types of solid bodies : Crystalline and amorphous bodies.
4. Crystalline structure of the metals and minerals.
5. Specific feature of the amorphous bodies.

II. *Retention :*

1. Is it possible to give the answer to the question "In what states is the water ?"
2. On what depends the aggregate state of a substance ?
3. What is common in different bodies which are made of the same metal?
4. What substances are amorphous bodies?
5. What is the specific feature of amorphous bodies?

III. *Home task.*

Lesson No. 2

Topic : Process of melting and solidification of crystalline substances.

Aim : To explain to the students specific feature of the process of melting and solidification of crystalline substances.

I. *Plan of the presentation of new materials :*

1. Demonstration of the process of melting and solidification of naphthalene.
2. Melting point of a substance.
3. Crystallization point of a substance.
4. Plotting of the graph of heating and melting.
5. Discussion of the graph on the basis of experiment.

II. *Retention :*

1. What does show the first part of graph?
2. In what state is the naphthalene in the first part of the graph?
3. What happens to the temperature during the whole process of melting?
4. In what state is naphthalene in the second part of the graph ?

III. *Home task.*

Lesson No. 3

Topic : The process of melting and crystallization from the point of view of molecular kinetic theory.

Aim : To explain to the students regularities in the process of melting and crystallization.

I. *Questions to pupils :*

1. What are the basic points of molecular kinetic theory?
2. What constitutes the internal energy of a body?

3. On what does the kinetic energy of molecules depend?

4. On what does potential energy of the molecules depend ?

5. What happens to the temperature of a body during the heating of crystalline naphthalene ?

6 Up to what degree the temperature of naphthalene is increased by heating?

7. How will you name the temperature at which the body melts at normal atmospheric pressure?

8. Does the temperature of naphthalene increase during the process of melting ?

II. *Plan of presentation of new material:*

1. The process of melting crystalline bodies is associated with the spending of energy.

2. The energy which is required for the process of melting is taken from the energy given by the burning spirit.

3. The energy which is required for the process of melting crystalline bodies at an initial temperature which is less than the point of melting consists of two components q_1 and q_2.

4. Quantity of heat, q_1, is required for heating crystalline bodies from initial temperature upto the point of melting.

5. Quantity of heat, q_1, is spent to increase the speed of thermal motion of molecules of crystalline naphthalene and consequently increase their kinetic energy.

6. Quantity of heat, q_2, is required to melt crystalline bodies without any change of the temperature of the body.

7. Quantity of heat, q_2, is spent to increase the potential energy of molecules overcoming the force of interaction between those molecules.

8. The quantity of heat given off by the process of cooling of liquid naphthalene.

9. Quantity of heat given off by the process of crystallization.

III. *Home task.*

Lesson No. 4

Topic : Laboratory work, observation of the process of melting of naphthalene.

Aim : To give the students some practice in observing the process of melting of crystalline bodies.

I. *Short Introduction to laboratory work of the students :*

(*a*) The aim of laboratory work—observation of the process of heating and melting naphthalene.

(*b*) Record the temperature of naphthalene at the interval of 2 minutes.

(*c*) On the basis of data plot the graph of the process of heating and melting (see the picture of the graph in the textbook).

(*d*) Give the answer to the following questions:

1. At what temperature does the naphthalene starts melting ?

2. What happens to the amount of mass of crystalline and amount of liquid naphthalene during the process of melting?

3. What happens to the temperature of naphthalene after the naphthalene reaches the temperature of melting.

II. *Distribution of the full sets of equipment to the students on their tables.*

III. *Producing the laboratory work by students.*

IV. *Reports of students on the results of this laboratory work.*

V. *Home task.*

Lesson No. 5

Topic : Heat of fusion of the crystalline substance.

Aim : To explain to the students the physical idea of the heat of fusion.

I. *Plan of presentation of new material :*

1. Concept of heat of fusion of a substance.
2. The units of measuring the heat of fusion.
3. Table of heat of fusion for different substances.
4. Formula for calculating the quantity of heat which is required to melt crystalline bodies given at its melting point.

$q = L \times m$

5. Formula for calculating the quantity of heat, which is required to melt crystalline bodies at the initial temperature less than its melting point.

$q = S \times m\ (t_2^o - t_1^o) + L \times m$

6. Heat of crystallization of the substance.
7. Equality of the heat of fusion and heat of crystallization of the same substance.

II. *Retention :*

Solving qualitative problems.

III. *Home task.*

Lesson No. 6

Topic : Solving the problems on the process of melting and crystallization.

Aim : To help the students in acquiring skills of solving problems of this sub-topic. In this lesson before the teacher starts solving some problems it is desirable to remind the previous lesson by putting to students following questions :

1. What is the heat of fusion of the substance?

2. In what units can the heat of fusion be measured?

3. By what formula can we calculate the quantity of heat which is required for heating a body?

$q=s\times m\times(t_2^o—t_1^o)$

4. By what formula can we calculate quantity of heat which is given off by cooling of a body?

$q=s\times m\ (t_1^o—t_2^o)$

5. By what formula can we calculate the quantity of heat which is required for melting the crystalline bodies at its melting point?

$q=L\times m$

6. By what formula can we calculate the quantity of heat which is given off in the process of crystallization ?

$q=L\times m$

In the first problem it is desirable that this may be solved by the teacher on the blackboard with the explanation of the solution, and then on the basis of this example students must solve some problems of this sub-topic during this lesson.

IV. *Home task.*

Lesson No. 7

Topic : Evaporation and condensation.

Aim : To explain to the students the nature of the process of evaporation and condensation.

I. *Plan of presentation of new material :*

1. Consideration of some examples of transforming the liquid into the vapour and the reverse process from everyday life observations of the students.

2. Demonstration of evaporation of ether and spirit.

3. Demonstration of evaporation of crystalline substance—iodine (without liquid state of the substance).

4. The role of the process of evaporation and condensation in the water cycle in nature.

5. Explanation of the process of evaporation from the point of view of molecular kinetic theory.

II. *Retention :*

1. What is the process of condensation ?
2. What is the process of evaporation ?
3. Why the level of the water does not change in the oceans and the seas in spite of the process of evaporation from the surface of these big areas of water ?
4. Do crystalline bodies transform into vapour without going into the liquid state ?

III. *Home task.*

Lesson No. 8

Topic : Dependence of the rate of evaporation of a liquid at different conditions.

Aim : To explain the students some regularities in the process of evaporation.

I. *Plan of presentation of new material :*

1. Show that the time taken in the process of evaporation for a given mass of the liquid, other conditions being equal, is less when the free surface of the liquid is larger.
2. Show that the speed of the process of evaporation, other conditions being equal, is more when the temperature of evaporating liquid is greater.
3. Show that the speed of the process of evaporation depends on the property of the liquid itself, other conditions being similar.
4. Show that the time taken in the process of evaporation, other conditions being equal, is less when above the evaporating liquid there is motion of the air.
5. The process of evaporation is associated with cooling of the evaporating liquid.

II. *Retention ·*

Solving qualitative problems.

III. *Home task.*

Lesson No. 9

Topic : Explanation of the regularities of the process of evaporation from the point of view of molecular kinetic theory.

Aim : To show to the students the utility of molecular kinetic theory for understanding the experimental results of the process of evaporation.

I. *Questions to pupils* ·

1. How can you explain the process of evaporation of a liquid ?
2. On what does the rate of evaporation of the liquid depend ?
3. Solving qualitative problems on the process of evaporation and condensation.

II. *Plan of presentation of new material* :

1. Explanation of the dependence of the rate of evaporation on the area of the free surface of the liquid.
2. Explanation of the dependence of the rate of evaporation on the temperature of evaporating liquid.
3. Explanation of the dependence of the rate of evaporation on the properties of liquid.
4. Explanation of the dependence of the rate of evaporation on removing the vapour from above the surface of evaporating liquid.
5. The process of evaporation requires some amount of heat which is supplied from internal energy of the evaporating liquid.

Lesson No. 10

Topic : Boiling of water.

Aim : To consider the mechanism of the process of vaporization by boiling.

I. *Plan of presentation of new material* :

1. Consideration of some examples of boiling liquids from everyday life observations of the students.
2. Demonstration of heating and boiling water.

Note : While carrying out this demonstration it is necessary, on the basis of the data obtained from the measurement of the temperature of the water, to plot the graph of the process of heating and boiling water on the blackboard.

While performing this demonstration, mechanism of the process of boiling water should be recognized. For this purpose the teacher must emphasise on the students the following points:

(*a*) Some amount of air is dissolved in the water. This air exists in the tiny bubbles on the walls of the vessel.

(*b*) During the heating these bubbles increase in volume.

(*c*) In these bubbles goes the process of evaporation of the water.

(*d*) Due to increase in the pressure inside these bubbles, the volume of these bubbles is also increased.

(*e*) At a particular size of the bubbles the buoyant force acting upon the

bubbles can overcome the force of interaction between these bubbles and the walls of the vessel and push out these bubbles to the surface of the liquid due to which the water vapour is formed.

(*f*) The process of boiling starts when the pressure inside these bubbles reaches the value of the outside atmospheric pressure.

(*g*) The point of boiling of water at the normal atmospheric pressure is equal to 100° C.

(*h*) In order to produce vapour from liquid it is necessary first to heat this liquid from initial temperature up to the point of boiling and then give quantity of heat to transform this liquid into the vapour without changing the temperature.

II. *Home task.*

Lesson No. 11

Topic : Heat of vaporization.

Aim : To explain the students the process of heating and boiling from the point of view of molecular kinetic theory.

I. *Questions to pupils :*

1. By what two types of processes is it possible to transform the liquids into vapour?
2. What does constitute the bubbles in the water on the wall of the vessel which contains the water?
3. What happens with these bubbles during the process of heating the water?
4. What characterises the first section of the graph which was produced in the previous lesson?
5. What characterises the second section of the graph ?
6. At what temperature does the water start boiling?
7. What happens to the temperature of the water after it reaches the temperature of boiling point?

II. *Plan of presentation of new material :*

1. The process of vaporization by boiling requires some quantity of heat.
2. The quantity of heat which is required for the process of vaporization is supplied by the burning spirit
3. The quantity of heat which is necessary to transform the liquid into the vapour consists of two components.
4. First component is the quantity of heat—q_1 which is required for the process of heating the water from initial temperature up to the boiling point. It

means that this quantity of heat goes to increase the speed of thermal motion of molecules.

5. Therefore the quantity of heat—q_1 which is absorbed by water goes to increase internal energy of the water on account of increasing the kinetic energy of molecules.

6. The second component, the second quantity of heat—q_2 goes to transform the water into the vapour without changing the temperature.

7. Quantity of heat q_2 goes to overcome the force of interaction between molecules of water. Therefore, the quantity of heat goes to increase the internal energy of the vapour on account of the increase of potential energy of molecules of the water vapour.

8. Introduction of the concept of the specific heat of vaporization.

9. Units in which we can express the specific heat of vaporization.

10. Formula for calculating the quantity of heat, which is required for the process of vaporization.

$$q_2 = L \times m$$

$$q = S \times m \times (t_2^o - t_1^o) + L \times m$$

III. *Home task.*

Lesson No. 12

Topic : Laboratory work—"observation of the process of heating and boiling water."

Aim : To promote, among the students, some skills of right observation of the heating and boiling water and some skills of plotting the graph of this process.

I. *Introduction of the laboratory work :*

In this very short discussion teacher must explain the following points:

1. The name of laboratory work.
2. The aim of laboratory work.
3. Suggestions about the method of observation and measuring the temperature of the water; method of plotting the graph of the process of heating and boiling.
4. Organization of the work between small groups of students during this laboratory work.

After this the teacher with the help of some students must give total set of equipments on each table and the students must start this laboratory work.

II. *After the laboratory work, the students must be asked to give report of their work to the teacher.*

III. *Home task.*

Lesson No. 13

Topic : Solving problems on the process of vaporization.

Aim : To promote among the students the skills of solving the problems of this sub-topic.

I. In the first part of the lesson the teacher must remind some very important points of the process of boiling by putting some questions to all students of the class.

1. By what formula is it possible to calculate the quantity of heat which is required for increasing the temperature of a liquid by certain degrees?
2. In what units can we measure the specific heat of a substance?
3. By what formula is it possible to calculate the quantity of heat which is required for the process of vaporization of the liquid at its boiling point ?
4. By what formula is it possible to calculate the quantity of heat which is required for the process of vaporization of the liquid given at a certain temperature, which is less than its boiling point ?
5. In what units can we measure the heat of vaporization ?

II. After discussing these questions, the teacher must provide the solution of one of the problems on the blackboard with good explanations. Then on the basis of this example the students must solve some of the problems of the sub-topic (see the list of problems in this guide).

III. *Home task.*

Lesson No. 14

Topic : Process of condensation.

Aim : Explanation of the process of condensation from the point of view of molecular kinetic theory.

I. *Plan of presentation of new material :*

1. Consideration of some examples of condensation of water vapour from everyday life observations of the students.
2. Demonstration of condensation of water vapour (see picture of this demonstration in the textbook).
3. The quantity of heat, given off in the process of condensation.
4. Explanation of the process of condensation from the point of view of molecular kinetic theory.

II. *Retention :*

Solving some problems on condensation.

III. *Home task.*

Lesson No. 15

Topic : Heat of condensation.

Aim : To explain the concept of the heat of condensation.

I. *Plan of presentation of new material :*

1. Comparison of the quantity of heat which is given off by the water during the process of cooling with the quantity of heat which is given off in the process of condensation of water vapour of same mass and at the same temperature.
2. Concept of the heat of condensation.
3. Units in which the heat of condensation can be measured.
4. Formula for calculating the quantity of heat which is given off in the process of condensation.
5. Equality of the heat of vaporization and heat of condensation for the same substance.

II. *Retention* :

Solving some problems of condensation.

III. *Home task.*

Lesson No. 16

Topic : Boiling the water at higher than the normal atmospheric pressure.

Aim : Explain the dependence of boiling point of the liquid on the value of outside pressure.

I. *Plan of presentation of new material :*

1. Demonstration of boiling water at normal atmospheric pressure
2. Demonstration of boiling water at a pressure higher than the normal atmospheric pressure.
3. Demonstration of boiling water at a pressure less than the normal atmospheric pressure.
4. Boiling of a liquid depends on the value of outside pressure.
5. Application of the technique of boiling of water at high pressure for producing high temperature vapour.

II. *Retention :*

Solving some problems.

III. *Home task.*

Lesson No. 17

Topic : Solving different problems of all the topics of this chapter.

Aim : To strengthen the knowledge and skills of the chapter which will be tested in the next lesson.

I. *Plan of presentation :*

1. Retention of the basic points of the process of melting and crystallization (the graph of the process of melting crystalline substance, formula of calculating quantity of heat which is required for the process of melting, the units of measuring specific heat of a substance, units of measuring heat of fusion).
2. Solving the problems of melting and crystallization.
3. Retention of basic points of the process of evaporation.
4. Solving one of the problems of evaporation.
5. Retention of basic points of the process of boiling.
6. Solving one of the problems of the process of condensation.

II. *Home task.*

Lesson No. 18

Topic : Control testing of this chapter.

Aim : To check up the knowledge and skills of the students, which they have acquired during the study of this chapter.

For this lesson teacher must prepare at least 4 variants of the same control testing. All tests must consist of different types of problems. Each variant must include one quality problem on the process of evaporation and one quantity problem on the process of melting (or crystallization) or one problem of the process of boiling (or condensation). All the variants must be approximately of equal difficulty.